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SCIENTIFIC ENIGMAS.*

By LORD SALISBURY.

MY functions are of a more complicated character than usually is assigned to the occupants of this chair. As chancellor of the university it is my duty to tender to the British Association a hearty welcome, which it is my duty as president of the association to accept. As president of the association I convey, most unworthily, the voice of English science, as many worthy and illustrious presidents have done before me; but in representing the university I represent far more fittingly the learners who are longing to hear the lessons which the first teachers of English science have come as visitors to teach. I am bound to express on behalf of the university our sense of the good feeling toward that body which is the motive of this unusual arrangement. But as far as I am personally concerned, it is attended with some embarrassing results. In presence of the high priests of science I am only a layman, and all the skill of all the chemists the association contains will not transmute a layman into any more precious kind of metal.

Yet it is my hard destiny to have to address on scientific matters probably the most competent scientific audience in the world. If a country gentleman, who was also a colonel of volunteers, were by any mental aberration on the part of the commander-in-chief to be appointed to review an army corps at Aldershot, all military men would doubtless feel a deep compassion for his inevitable fate. I bespeak some spark of that divine emotion when I am attempting to discharge under similar conditions a scarcely less hopeless duty. At least, however, I have the consolation of feeling that I am free from some of the anxieties which have fallen to those who have preceded me as presidents in this city. The relations of the association and the university are those of entire sympathy and good will, as becomes common workers in the sacred cause of diffusing enlightenment and knowledge.

But we must admit that it was not always so. A curious record of a very different state of feeling came to light last year in the interesting biography of Dr. Pusey, which is the posthumous work of Canon Liddon. In it is related the first visit of the association to Oxford in 1832. Mr. Keble, at that time a leader of university thought, writes indignantly to his friend to complain that the honorary degree of D.C.L. had been bestowed upon some of the most distinguished members of the association: "The Oxford doctors," he says, "have truckled sadly to the spirit of the times in receiving the hodge podge of philosophers as they did." It is amusing, at this distance of time, to note the names of the hodge-podge of philosophers whose academical distinctions so sorely vexed Mr. Keble's gentle spirit. They were Brown, Brewster, Faraday and Dalton. When we recollect the lovable and serene character of Keble's nature, and that he was at that particular date probably the man in the university who had the greatest power over other men's minds, we can measure the distance we have traversed since that time; and the rapidity with which the converging paths of these two intellectual luminaries, the university and the association, have approximated to each other. This sally of Mr. Keble's was no passing or accidental caprice. It represented a deep-seated sentiment in this place of learning, which had its origin in historic causes, and which has only died out in our time.

One potent cause of it was that both bodies were teachers of science, but did not then in any degree attach the same meaning to that word. Science with the university for many generations bore a signification different from that which belongs to it in this assembly. It represented the knowledge which alone in the middle ages was thought worthy of the name of science. It was the knowledge gained, not by external observation, but by mere reflection. The student's microscope was turned inward upon the recesses of his own brain; and when the supply of facts and realities failed, as it very speedily did, the scientific imagination was not wanting to furnish to successive generations an interminable series of conflicting speculations. That science—science in our academical sense—had its day of rapid growth, of boundless aspiration, of enthusiastic votaries. It fascinated the rising intellect of the time, and it is said—people were not particular about figures in those days—that its attractions were at one time potent enough to gather round the university thirty thousand students, who for the sake of learning its teaching were willing to endure a life of the severest hardship. Such a state of feeling is now an archæological curiosity. The revolt against Aristotle is now some three centuries old. But the mental sciences which were supposed to rest upon his writings have retained some of their ascendency even till this day, and have only slowly and jealously admitted the rivalry of the growing sciences of observation.

The subject is interesting to us, as this undecided state of feeling colored the experiences of this association at its last Oxford visit, nearly a generation later, in 1860. The warmth of the encounters which then took place has left a vivid impression on the minds of those who are old enough to have witnessed them. That much energy was on that occasion converted into heat may, I think, be inferred from the mutual distance which the two bodies have since maintained. Whereas the visit of 1832 was succeeded by another visit in fifteen years, and the visit of 1847 was succeeded by another visit in thirteen years, the year 1860 was followed by a long and dreary interval of separation, which has only now, after four-and-thirty years, been terminated. It has required the lapse of a generation to draw the curtain of oblivion over those animated scenes. It was popularly supposed that deep divergences upon questions of religion were the motive force of those high controversies. To some extent that impression was correct. But men do not always discern the motives which are really urging them, and I suspect that in many cases religious apprehensions only masked the resentment of the older learning at the appearance and claims of its younger rival. In any case there is something worthy of note, and something that conveys encouragement, in the difference of the feeling which prevails now and the feeling that was indicated then. Few men are now influenced by the strange idea that questions of religious belief depend on the issues of physical research. Few men, whatever their creed, would now seek their geology in the books of their religion, or, on the other hand, would fancy that the laboratory or the microscope could help them to penetrate the mysteries which hang over the nature and the destiny of the soul of man. And the old learning no longer contests the share in education which is claimed by the new, or is blind to the supreme influence which natural knowledge is exercising in moulding the human mind.

A study of the addresses of my learned predecessors in this office shows me that the main duty which it

THE MARQUIS OF SALISBURY DELIVERING HIS PRESIDENTIAL ADDRESS BEFORE THE BRITISH ASSOCIATION, OXFORD.

* Inaugural address before the British Association, Oxford, August, 1894, by the Most Hon. the Marquis of Salisbury, K.G., D.C.L., F.R.S., Chancellor of the University of Oxford, President.

falls to a president to perform in his introductory address is to remind you of the salient points in the annals of science since last the association visited the town in which he is speaking. Most of them have been able to lay before you in all its interesting detail the history of the particular science of which each one of them was the eminent representative. If I were to make any such attempt, I should only be telling you with very inadequate knowledge a story which is from time to time told you, as well as it can be told, by men who are competent to deal with it. It will be more suitable to my capacity if I devote the few observations I have to make to a survey, not of our science, but of our ignorance.

We live in a small bright oasis of knowledge surrounded on all sides by a vast unexplored region of impenetrable mystery. From age to age the strenuous labor of successive generations wins a small strip from the desert and pushes forward the boundary of knowledge. Of such triumphs we are justly proud. It is a less attractive task—but yet it has its fascination as well as its uses—to turn our eyes to the undiscovered country which still remains to be won, to some of the stupendous problems of natural study which still defy our investigation. Instead, therefore, of recounting to you what has been done, or trying to forecast the discoveries of the future, I would rather draw your attention to the condition in which we stand toward three or four of the most important physical questions which it has been the effort of the last century to solve.

THE ENIGMAS OF THE ELEMENTS.

Of the scientific enigmas which still, at the end of the nineteenth century, defy solution, the nature and origin of what are called the elements is the most notable. It is not, perhaps, easy to give a precise logical reason for the feeling that the existence of our sixty-five elements is a strange anomaly and conceals some much simpler state of facts. But the conviction is irresistible. We cannot conceive, on any possible doctrine of cosmogony, how these sixty-five elements came into existence. A third of them form the substance of this planet. Another third are useful, but somewhat rare. The remaining third are curiosities scattered haphazard, but very scantily, over the globe, with no other apparent function but to provide occupation for the collector and the chemist. Some of them are so like each other that only a chemist can tell them apart; others differ immeasurably from each other in every conceivable particular. In cohesion, in weight, in conductivity, in melting point, in chemical proclivities they vary in every degree. They seem to have as much relation to each other as the pebbles on a sea beach, or the contents of an ancient lumber room. Whether you believe that creation was the work of design or of inconscient law, it is equally difficult to imagine how this random collection of dissimilar materials came together. Many have been the attempts to solve this enigma; but up till now they have left it more impenetrable than before. A conviction that here was something to discover lay beneath the persistent belief in the possibility of the transmutation of other metals into gold, which brought the alchemy of the middle ages into being.

When the immortal discovery of Dalton established that the atoms of each of these elements have a special weight of their own, and that consequently they combine in fixed ponderable proportions from which they never depart, it renewed the hope that some common origin of the elements was in sight. The theory was advanced that all these weights were multiples of the weight of hydrogen—in other words, that each elementary atom was only a greater or a smaller number of hydrogen atoms compacted by some strange machinery into one. The most elaborate analyses, conducted by chemists of the highest eminence—conspicuously by the illustrious Stas—were directed to the question whether there was any trace in fact of the theoretic idea that the atoms of each element consist of so many atoms or even of so many half atoms of hydrogen. But the reply of the laboratories has always been clear and certain—that there is not in the facts the faintest foundation for such a theory.

Then came the discovery of the spectrum analysis, and men thought that with an instrument of such inconceivable delicacy we should at last find out something as to the nature of the atom. The result has been wholly disappointing. Spectrum analysis in the hands of Dr. Huggins and Mr. Lockyer and others has taught us things of which the world little expected to be told. We have been enabled to measure the speed with which clouds of blazing hydrogen course across the surface of the sun; we have learnt the pace—the fabulous pace—at which the most familiar stars have been for ages approaching to or receding from our planet, without apparently affecting the proportions of the patterns which as far as historical record goes back they have always delineated on the evening sky. We have received some information about the elementary atoms themselves. We have learnt that each sort of atom when heated strikes upon the ether a vibration, or set of vibrations, whose rate is all its own; and that no one atom or combination of atoms in producing its own spectrum encroaches even to the extent of a single line upon the spectrum that is peculiar to its neighbor. We have learnt that the elements which exist in the stars and specially in the sun are mainly those with which we are familiar upon earth. There are a few lines in excess to which we can give no terrestrial name; and there are some still more puzzling gaps in our list. It is a great aggravation of the mystery which besets the question of the elements, that among the lines which are absent from the spectrum of the sun, those of nitrogen and oxygen stand first. Oxygen constitutes the largest portion of the solid and liquid substance of our planet, so far as we know it; and nitrogen is very far the predominant constituent of our atmosphere. If the earth is a detached bit whirled off the mass of the sun, as cosmogonists love to tell us, how comes it that in leaving the sun we cleaned him out so completely of his nitrogen and oxygen that not a trace of these gases remains behind to be discovered even by the sensitive vision of the spectroscope?

All these things the discovery of the spectrum analysis has added to our knowledge; but it has left us as ignorant as ever as to the nature of the capricious differences which separate the atoms from each other, or the cause to which those differences are due.

In the last few years the same enigma has been approached from another point of view by Prof. Mendeleeff. The periodic law which he has discovered reflects on him all the honor that can be earned by ingenious, laborious, and successful research. He has shown that this perplexing list of elements can be divided into families of about seven, speaking very roughly; that those families all resemble each other in this, that as to weight, volume, heat, and laws of combination, the members of each family are ranked among themselves in obedience to the same rule. Each family differs from the others; but each internally is constructed upon the same plan. It was a strange discovery—strangest of all in its manifest defects. For in the plan of his families there were blanks left; places not filled up because the properly constituted elements required according to his theory had not been found to fill them. For the moment their absence seemed a weakness in the professor's idea, and gave an arbitrary aspect to his scheme. But the weakness was turned into strength when, to the astonishment of the scientific world, three of the elements which were missing made their appearance in answer to his call. He had described beforehand the qualities they ought to have; and gallium, germanium, and scandium, when they were discovered shortly after the publication of his theory, were found to be duly clothed with the qualities he required in each. This remarkable confirmation has left Mendeleeff's periodic law in an unassailable position. But it has rather thickened than dissipated the mystery which hangs over the elements. The discovery of these co-ordinate families dimly points to some identical origin, without suggesting the method of their genesis or the nature of their common parentage. If they were organic beings, all our difficulties would be solved by muttering the comfortable word "evolution"—one of those indefinite words from time to time vouchsafed to humanity, which have the gift of alleviating so many perplexities and masking so many gaps in our knowledge But the families of elementary atoms do not breed; and we cannot therefore ascribe their ordered difference to accidental variations perpetuated by heredity under the influence of natural selection. The rarity of iodine, and the abundance of its sister chlorine, cannot be attributed to the survival of the fittest in the struggle for existence. We cannot account for the minute difference which persistently distinguishes nickel from cobalt, by ascribing it to the recent inheritance by one of them of an advantageous variation from the parent stock.

The upshot is that all these successive triumphs of research, Dalton's, Kirchhoff's, Mendeleeff's, greatly as they have added to our store of knowledge, have gone but little way to solve the problem which the elementary atoms have for centuries presented to mankind. What the atom of each element is, whether it is a movement, or a thing, or a vortex, or a point having inertia, whether there is any limit to its divisibility, and, if so, how that limit is imposed, whether the long list of elements is final, or whether any of them have any common origin, all these questions remain surrounded by a darkness as profound as ever. The dream which lured the alchemists to their tedious labors, and which may be said to have called chemistry into being, has assuredly not been realized, but it has not yet been refuted. The boundary of our knowledge in this direction remains where it was many centuries ago.

THE ENIGMA OF THE ETHER.

The next discussion to which I should look in order to find unsolved riddles which have hitherto defied the scrutiny of science, would be the question of what is called the ether. The ether occupies a highly anomalous position in the world of science. It may be described as a half-discovered entity. I dare not use any less pedantic word than entity to designate it, for it would be a great exaggeration of our knowledge if I were to speak of it as a body or even as a substance. When nearly a century ago Young and Fresnel discovered that the motions of an incandescent particle were conveyed to our eyes by undulation, it followed that between our eyes and the particle there must be something to undulate. In order to furnish that something, the notion of the ether was conceived, and for more than two generations the main, if not the only, function of the word ether has been to furnish a nominative case to the verb "to undulate." Lately our conception of this entity has received a notable extension. One of the most brilliant of the services which Prof. Maxwell has rendered to science has been the discovery that the figure which expressed the velocity of light also expressed the multiplier required to change the measure of static or passive electricity into that of dynamic or active electricity. The interpretation reasonably affixed to this discovery is that, as light and the electric impulse move approximately at the same rate through space, it is probable that the undulations which convey them are undulations of the same medium. And as induced electricity penetrates through everything, or nearly everything, it follows that the ether through which its undulations are propagated must pervade all space, whether empty or full, whether occupied by opaque matter or transparent matter, or by no matter at all. The attractive experiments by which the late Prof. Hertz illustrated the electric vibrations of the ether will only be alluded to by me in order that I may express the regret deeply and generally felt that death should have terminated prematurely the scientific career which had begun with such brilliant promise and such fruitful achievements. But the mystery of the ether, though it has been made more fascinating by these discoveries, remains even more inscrutable than before. Of this all-pervading entity we know absolutely nothing except this one fact, that it can be made to undulate. Whether outside the influence of matter on the motion of its waves, ether has any effect on matter or matter upon it, is absolutely unknown. And even its solitary function of undulating ether performs in an abnormal fashion which has caused infinite perplexity. All fluids that we know transmit any blow they have received by waves which undulate backward and forward in the path of their own advance. The ether undulates athwart the path of the wave's advance. The genius of Lord Kelvin has recently discovered what he terms a labile state of equilibrium, in which a fluid that is infinite in its extent may exist, and may undulate in this eccentric fashion without outraging the laws of mathematics. I am no mathematician, and I cannot judge whether this reconciliation of the action of the ether with mechanical law is to be looked upon as a permanent solution of the question, or is only what diplomatists call a modus vivendi. In any case it leaves our knowledge of the ether in a very rudimentary condition. It has no known qualities except one, and that quality is in the highest degree anomalous and inscrutable. The extended conception which enables us to recognize ethereal waves in the vibrations of electricity has added infinite attraction to the study of those waves, but it carries its own difficulties with it. It is not easy to fit in the theory of electrical ether waves with the phenomena of positive and negative electricity, and as to the true significance and cause of those counteracting and complementary forces to which we give the provisional names of negative and positive, we know about as much now as Franklin knew a century and a half ago.

THE ENIGMAS OF LIFE.

I have selected the elementary atoms and the ether as two instances of the obscurity that still hangs over problems which the highest scientific intellects have been investigating for several generations. A more striking but more obvious instance still is life—animal and vegetable life—the action of an unknown force on ordinary matter. What is the mysterious impulse which is able to strike across the ordinary laws of matter, and twist them for a moment from their path?

Some people demur to the use of the term "vital force" to designate this impulse. In their view the existence of such a force is negatived by the fact that chemists have been able by cunning substitutions to produce artificially the peculiar compounds which in nature are only found in organisms that are or have been living. These compounds are produced by some living organism in the performance of the ordered series of functions proper to its brief career. To counterfeit them—as has been done in numerous cases—does not enable us to do what the vital force alone can effect—to bring the organism itself into existence, and to cause it to run its appointed course of change. This is the unknown force which continues to defy not only our imitation but our scrutiny.

Biology has been exceptionally active and successful during the last half century. Its triumphs have been brilliant, and they have been rich enough not only in immediate result, but in the promise of future advance. Yet they give at present no hope of penetrating the great central mystery. The progress which has been made in the study of microscopic life has been very striking, whether or not the results which are at present inferred from it can be taken as conclusive. Infinitesimal bodies found upon the roots of plants have the proud office of capturing and taming for us the free nitrogen of the air, which, if we are to live at all, we must consume and assimilate, and yet which, without the help of our microscopic ally, we could not draw for any useful purpose from the ocean of nitrogen in which we live.

Microscopic bodies are convicted of causing many of the worst diseases flesh is heir to, and the guilt of many more will probably be brought home to them in due time; and they exercise a scarcely less sinister or less potent influence on our race by the plagues with which they destroy some of the most valuable fruits of husbandry, such as the potato, the mulberry and the vine. Almost all their power resides in the capacity of propagating their kind with infinite rapidity, and up to this time science has been more skillful in describing their ravages than in devising means to hinder them.

It would be ungrateful not to mention two brilliant exceptions to this criticism. The antiseptic surgery which we owe chiefly to Lister, and the inoculation against anthrax, hydrophobia, and perhaps some other diseases, which we owe to Pasteur, must be recorded as splendid victories over the countless legions of our infinitesimal foes. Results like these are the great glory of the scientific workers of the past century. Men may, perhaps, have overrated the progress of nineteenth century research in opening the secrets of nature; but it is difficult to overrate the brilliant service it has rendered in ministering to the comforts and diminishing the sufferings of mankind.

THE DARWIN THEORY.

If we are not able to see far into the causes and origin of life in our own day, it is not probable that we shall deal more successfully with the problem as it arose many million years ago. Yet certainly the most conspicuous event in the scientific annals of the last half century has been the publication of Mr. Darwin's work on the "Origin of Species," which appeared in 1859. In some respects, in the depth of the impression which it made on scientific thought, and even on the general opinion of the world, its momentous effect can hardly be overstated. But at this distance of time it is possible to see that some of its success has been due to adventitious circumstances. It has had the chance of enlisting among its champions some of the most powerful intellects of our time, and perhaps the still happier fortune of appearing at a moment when it furnished an armory of weapons to men, who were not scientific, for use in the bitter but transitory polemics of the day. But far the largest part of its accidental advantages was to be found in the remarkable character and qualifications of its author. The equity of judgment, the simple-minded love of truth and the patient devotion to the pursuit of it through years of toil and of other conditions the most unpropitious—these things endeared to numbers of men everything that came from Charles Darwin, apart from its scientific merit or literary charm. And whatever final value may be assigned to his doctrine, nothing can ever detract from the luster shed upon it by the wealth of his knowledge and the infinite ingenuity of his resource. The intrinsic power of his theory is shown at least in this one respect, that in the department of knowledge with which it is concerned it has effected an entire revolution in the methods of research. Before his time the study of living nature had a tendency to be merely statistical; since his time it has become predominantly historical. The consideration how any organic body came to be what it is occupies a far larger area in any inquiry now than the mere description of its actual condition; but this question was not predominant—it may almost be said to have been ignored—in the botanical and zoological study of sixty years ago.

Another lasting and unquestioned effect has resulted from Darwin's work. He has, as a matter of fact, disposed of the doctrine of the immutability of species. It has been mainly associated in recent days with the honored name of Agassiz, but with him has disappeared the last defender of it who could claim the attention of the world. Few now are found to doubt that animals separated by differences far exceeding those that distinguished what we know as species have yet descended from common ancestors. But there is much less agreement as to the extent to which this common descent can be assumed, or the process by which it has come about. Darwin himself believed that all animals were descended from "at most four or five progenitors"—adding that "there was grandeur in the view that life had been originally breathed by the Creator into a few forms or one." Some of his more devoted followers, like Prof. Haeckel, were prepared to go a step farther and to contemplate a crystal as the probable ancestor of the whole fauna and flora of this planet.

To this extent the Darwinian theory has not effected the conquest of scientific opinion; and still less is there any unanimity in the acceptance of natural selection as the sole or even the main agent of whatever modifications may have led up to the existing forms of life. The deepest obscurity still hangs over the origin of the infinite variety of life. Two of the strongest objections to the Darwinian explanation appear still to retain all their force.

I think Lord Kelvin was the first to point out that the amount of time required by the advocates of the theory for working out the process they had imagined could not be conceded without assuming the existence of a totally different set of natural laws from those with which we are acquainted. His view was not only based on profound mechanical reasoning, but it was so plain that any layman could comprehend it. Setting aside arguments deduced from the resistance of the tides, which may be taken to transcend the lay understanding, his argument from the refrigeration of the earth requires little science to apprehend it. Everybody knows that hot things cool, and that according to their substance they take more or less time in cooling. It is evident from the increase of heat as we descend into the earth that the earth is cooling, and we know by experiment, within certain wide limits, the rate at which its substances, the matters of which it is constituted, are found to cool. It follows that we can approximately calculate how hot it was so many million years ago. But if at any time it was hotter at the surface by 50° F. than it is now, life would then have been impossible upon the planet, and, therefore, we can, without much difficulty, fix a date before which organic life on earth cannot have existed. Basing himself on these considerations, Lord Kelvin limited the period of organic life upon the earth to a hundred million years, and Prof. Tait, in a still more penurious spirit, cut that hundred down to ten. But on the other side of the account stand the claims of the geologists and biologists. They have reveled in the prodigality of the ciphers which they put at the end of the earth's hypothetical life. Long cribbed and cabined within the narrow bounds of the popular chronology, they have exulted wantonly in their new freedom. They have lavished their millions of years with the open hand of a prodigal heir indemnifying himself by present extravagance for the enforced self-denial of his youth. But it cannot be gainsaid that their theories require at least all this elbow room. If we think of that vast distance over which Darwin conducts us from the jelly fish lying on the primeval beach to man as we know him now; if we reflect that the prodigious change requisite to transform one into the other is made up of a chain of generations, each advancing by a minute variation from the form of its predecessor, and if we further reflect that these successive changes are so minute that in the course of our historical period—say three thousand years—this progressive variation has not advanced by a single step perceptible to our eyes, in respect to man or the animals and plants with which man is familiar, we shall admit that for a chain of change so vast, of which the smallest link is longer than our recorded history, the biologists are making no extravagant claim when they demand at least many hundred million years for the accomplishment of the stupendous process.

Of course, if the mathematicians are right, the biologists cannot have what they demand. If for the purposes of their theory, organic life must have existed on the globe more than a hundred million years ago, it must, under the temperature then prevailing, have existed in a state of vapor. The jelly fish would have been dissipated in steam long before he had had a chance of displaying the advantageous variation which was to make him the ancestor of the human race. I see, in the eloquent discourse of one of my most recent and most distinguished predecessors in this chair, Sir Archibald Geikie, that the controversy is still alive. The mathematicians sturdily adhere to their figures, and the biologists are quite sure the mathematicians must have made a mistake. I will not get myself into the line of fire by intervening in such a controversy. But until it is adjusted the laity may be excused for returning a verdict of "not proven" upon the wider issues the Darwinian school has raised.

The other objection is best stated in the words of an illustrious disciple of Darwin, who has recently honored this city by his presence—I refer to Prof. Weismann. But in referring to him I cannot but give, in passing, a feeble expression to the universal sorrow with which in this place the news was received that Weismann's distinguished antagonist, Prof. Romanes, had been taken from us in the outset and full promise of a splendid scientific career.

The gravest objection to the doctrine of natural selection was expressed by Weismann in a paper published a few months ago, not as agreeing to the objection, but as resisting it; and therefore his language may be taken as an impartial statement of the difficulty. "We accept natural selection," he says, "not because we are able to demonstrate the process in detail, not even because we can with more or less ease imagine it, but simply because we must—because it is the only possible explanation that we can conceive. We must assume natural selection to be the principle of the explanation of the metamorphoses, because all other apparent principles of explanation fail us, and it is inconceivable that there could yet be another capable of explaining the adaptation of organisms without assuming the help of a principle of design."

There is the difficulty. We cannot demonstrate the process of natural selection in detail; we cannot even, with more or less ease, imagine it. It is purely hypothetical. No man, so far as we know, has ever seen it at work. An accidental variation may have been perpetuated by inheritance, and in the struggle for existence the bearer of it may have replaced, by virtue of the survival of the fittest, his less improved competitors; but as far as we know no man or succession of men have ever observed the whole process in any single case, and certainly no man has recorded the observation. Variation by artificial selection, of course, we know very well; but the intervention of the cattle breeder and the pigeon fancier is the essence of artificial selection. It is effected by their action in crossing, by their skill in bringing the right mates together to produce the progeniture they want. But in natural selection who is to supply the breeder's place? Unless the crossing is properly arranged, the new breed will never come into being. What is to secure that the two individuals of opposite sexes in the primeval forest, who have been both accidentally blessed with the same advantageous variation, shall meet, and transmit by inheritance that variation to their successors? Unless this step is made good, the modification will never get a start; and yet there is nothing to insure that step, except pure chance. The law of chances takes the place of the cattle breeder and the pigeon fancier. The biologists do well to ask for an immeasurable expanse of time, if the occasional meetings of advantageously varied couples from age to age are to provide the pedigree of modifications which unite us to our ancestor, the jelly fish. Of course, the struggle for existence, and the survival of the fittest, would, in the long run, secure the predominance of the stronger breed over the weaker. But it would be of no use in setting the improved breed going. There would not be time. No possible variation which is known to our experience, in the short time that elapses in a single life between the moment of maturity and the age of reproduction, could enable the varied individual to clear the field of all competitors, either by slaughtering or starving them out. But unless the struggle for existence took this summary and internecine character, there would be nothing but mere chance to secure that the advantageously varied bridegroom at one end of the wood should meet the bride who, by a happy contingency, had been advantageously varied in the same direction at the same time at the other end of the wood. It would be a mere chance if they ever knew of each other's existence—a still more unlikely chance that they should resist on both sides all temptations to a less advantageous alliance. But unless they did so the new breed would never even begin, let alone the question of its perpetuation after it had begun. I think Prof. Weismann is justified in saying that we cannot, either with more or less ease, imagine the process of natural selection.

It seems strange that a philosopher of Prof. Weismann's penetration should accept as established a hypothetical process the truth of which he admits that he cannot demonstrate in detail, and the operation of which he cannot even imagine. The reason that he gives seems to me instructive of the great danger scientific research is running at the present time—the acceptance of mere conjecture in the name and place of knowledge, in preference to making frankly the admission that no certain knowledge can be attained. "We accept natural selection," he says, "because we must—because it is the only possible explanation that we can conceive." As a politician, I know that argument very well. In political controversy it is sometimes said of a disputed proposal that it "holds the field," that it must be accepted because no possible alternative has been suggested. In politics there is occasionally a certain validity in the argument, for it sometimes happens that some definite course must be taken, even though no course is free from objection. But such a line of reasoning is utterly out of place in science. We are under no obligation to find a theory, if the facts will not provide a sound one. To the riddles which nature propounds to us the profession of ignorance must constantly be our only reasonable answer. The cloud of impenetrable mystery hangs over the development and still more over the origin of life. If we strain our eyes to pierce it, with the foregone conclusion that some solution is and must be attainable, we shall only mistake for discoveries the figments of our own imagination. Prof. Weismann adds another reason for his belief in natural selection, which is certainly characteristic of the time in which we live. "It is inconceivable," he says, "that there should be another principle capable of explaining the adaptation of organisms without assuming the help of a principle of design." The whirligig of time assuredly brings its revenges. Time was, not very long ago, when the belief in creative design was supreme. Even those who were sapping its authority were wont to pay it a formal homage, fearing to shock the public conscience by denying it. Now the revolution is so complete that a great philosopher uses it as a reductio ad absurdum, and prefers to believe that which can neither be demonstrated in detail, nor imagined, rather than run the slightest risk of such a heresy.

I quite accept the professor's dictum that if natural selection is rejected we have no resource but to fall back on the mediate or immediate agency of a principle of design. In Oxford, at least, he will not find that argument is conclusive, nor, I believe, among scientific men in this country generally, however imposing the names of some whom he may claim for that belief. I would rather lean to the conviction that the multiplying difficulties of the mechanical theory are weakening the influence it once had acquired. I prefer to shelter myself in this matter behind the judgment of the greatest living master of natural science among us, Lord Kelvin, and to quote as my own concluding words the striking language with which he closed his address from this chair more than twenty years ago: "I have always felt," he said, "that the hypothesis of natural selection does not contain the true theory of evolution, if evolution there has been in biology. . . . I feel profoundly convinced that the argument of design has been greatly too much lost sight of in recent zoological speculations. Overpoweringly strong proofs of intelligent and benevolent design lie around us, and if ever perplexities, whether metaphysical or scientific, turn us away from them for a time, they come back upon us with irresistible force, showing to us through nature the influence of a free will, and teaching us that all living things depend on one everlasting Creator and Ruler."

SHOES FOR WALKING.

WE make the following abstract from an interesting article by Eugene Lamb Richards in the Century Magazine for August:

In order to obtain a correct form for my shoes I made plaster casts. In a box large enough to contain both feet I made a partition and covered the bottom with a layer of putty. Then I put each foot in the putty, thus making an impression. Into the impression I poured plaster of Paris. On lasts formed from these models I obtained the best possible shoes.

The modern shoe is made partly for use and partly for show. The part that is for show is the heel. The heel is an unnatural device. It inclines the foot forward, stubbing the toes, and it also brings the weight of the body too far forward, necessitating an unnatural crook in the knees. After twelve years of walking I discarded the heel from walking shoes, though so far deferring to fashion as to keep it for wear in the cities, and going to the expense of having two pairs of lasts made on the models referred to—one pair for heeled and one for heelless shoes.

INCORRECT FORM OF WALKING LAST.

If any person interested in having a correct shoe will take the trouble to examine the various lasts on which shoes are made, he will find that they have the form of the last in the figure labeled "incorrect form." Ten chances to one they will be of worse form, being pointed so as to pinch the toes. A correct shoe for walking can never be made on such lasts. They are meant for heeled shoes. If a shoe without a heel is made on this kind of last, the foot will not rest flat, but will turn up at the toes.

By using a correct last, the sole of the foot from heel to toe will rest flat, as nature intended it to do, and the weight of the body will be distributed over the whole surface. In the shoe made on a bad last the weight is brought unevenly on different parts of the foot. In a long walk this uneven distribution of weight makes a great difference in the fatigue of the foot.

CORRECT FORM OF WALKING LAST.

A laced shoe is to be preferred to any other.

Another improvement which I made was in doing away with the lining of the shoe. Still another improvement was in dispensing with all pegs. Hand-made shoes are generally "lasted" with wooden pegs. When the last is pulled out of the shoe the pegs stick up inside around the edge of the insole like so many nails. The shoemaker cuts them off with a knife, and then rasps them down. After the shoe has been in use some time and the leather becomes dry from wear, these pegs work up, and are one cause of the blistering of the feet. I found that a shoe could be manufactured without the use of these wooden pegs, so that when the shoe was taken from the last there was nothing to blister the feet, or, in other words, so that the insole could be made perfectly smooth. To obviate the discomfort caused by seams in the shoe, I have each of my shoes made of one large piece of leather, with an additional small piece set in on one side, as shown in the accompanying cut.

CORRECT FORM OF WALKING SHOE.

Another frequent cause of discomfort in walking is the sock. Most socks are manufactured with seams, and are pointed at the toe. These seams on a long day's tramp will cause blisters. If a person who wishes to become a walker will exercise care in the selection of his socks, he can obtain them without seams and square-toed. Woolen socks are to be preferred to cotton ones.

To travel properly, the walker must have two pairs of shoes, one pair made with light uppers and soles, the other pair with heavy uppers, heavy soles and "bellows" tongue. In addition to the convenience of having shoes adapted to the weather, the change of shoe after a long walk is a great relief.

METHODS OF MINE TIMBERING.*

By W. H. STORMS, Assistant in the Field.

THE excavation of any considerable amount of earth, or rock, beneath the surface of the ground usually necessitates that the roof, and not infrequently the sides, of such excavation be sustained artificially to prevent caving. In these later years the size of underground excavations is so great, as compared with those formerly made, that the ingenuity and skill of the miner is taxed to the utmost limit. So successful, however, have miners become in devising novel methods to meet daily exigencies that the obstacles usually encountered in mining, among which are flaky rock roofs; soft running ground; floods of water, sometimes scalding hot; and worst of all, swelling ground with heavy pressure from all sides, including the bottom, have mostly been successfully overcome.

Before Deidesheimer's "square set" system came into use, the ingenious placing of posts, caps, and "stulls" constituted the only method of timbering, the multitude of conditions met in the mines making the combinations almost endless. Where veins occur in firm, solid rock, being perpendicular, or near it, the

ENTRANCE TO AN OLD MINE IN HONDURAS

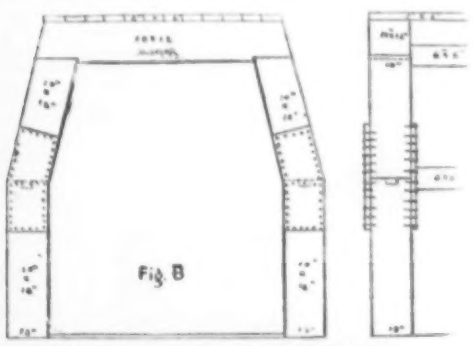
Fig. 1.

danger of caving is greatly lessened, and the amount of timber required is reduced to a minimum, but these conditions are exceptional.

Veins dip at all angles between perpendicular and horizontal, and vary greatly in width. Moreover, the character of the wall rock, as well as of the ore itself, is so variable that unexpected problems are encountered daily. The shape of large bodies of ore is a matter of great importance in determining the system of timbering to be employed.

Through all this variety and change in form, dip, size, and character of the vein or deposit, and in the inclosing walls, certain established principles are followed in sustaining the roof and sides, the constant aim being to prevent caving, and to avoid such a catastrophe timbers are placed with a view of holding the rock masses in place, and always in such a way as to receive the strain directly. Those timbers which reach from wall to wall of an inclined vein (stulls) are not set at right angle to the pitch of the hanging wall, but at a somewhat higher angle. The reason is obvious, for, if placed at a right angle, should a subsidence of the wall occur, the timber, partaking of this movement, at its upper end, would then have a tendency to fall of its own weight, whereas, if set originally above an angle of 90 degrees with the hanging wall, the subsidence of that wall only serves to wedge and hold the timber support more firmly, when it must bend and break before falling. When properly placed, stull timbers usually give sufficient warning of their weakness to permit of placing additional timbers and subsequently the removal and replacement of old or weak timbers.

To make an understanding of the various practices more comprehensive, a number of drawings have been introduced in this article. As a matter of course certain exigencies are likely to arise, the character of



ENTRANCE TO TUNNEL, CALAVERAS CONSOLIDATED MINE. CARSON HILL, CALAVERAS CO., CAL.

which has not been anticipated, but in all cases the principles applied remain the same, and it is thought that the conditions most likely to occur have been treated fully enough to meet the demands of metalliferous mining generally.

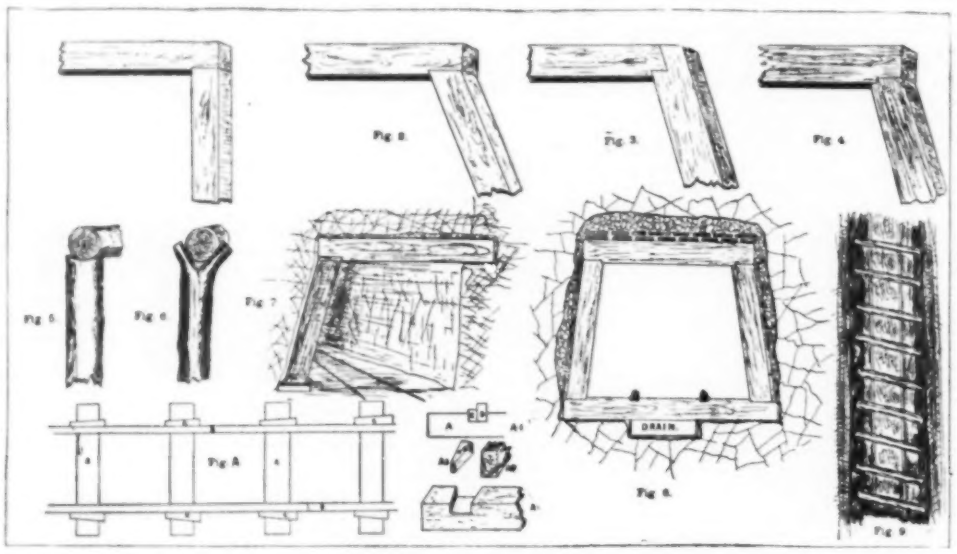
KINDS OF TIMBER USED.

In some instances solid masonry is built to sustain certain portions of mines, and in late years iron has been introduced as a substitute for timber, but in American mines timber is most commonly employed. Ordinarily the location of the mine determines the kind of timber. Pine of various kinds is more extensively used than any other. Sugar pine and spruce are preferred when obtainable, but yellow pine is by far the most common. Oak is gladly taken when good sticks of sufficient size can be found. There are oak timbers in mines in Mariposa County, apparently sound, that have been in place for twenty years. They certainly outlast any other timber. Cottonwood and redwood are sometimes used when no other is obtainable, but are not at all desirable. In the desert in this State, in parts of Arizona and Nevada, miners take any timber they can get, even resorting to the yucca, which answers quite well for a time in that dry climate when the pressure is not too great. At Silver Reef, in San Bernardino County, green yuccas were used in timbering a drift. They still stand in fair condition, having been in place five years. The superintendent of the Gover Mine, Amador County, California, has commenced some experiments with spruce and sugar pine, placing them side by side in the same set in the lower levels of his mine, to test their durability.

* From Bulletin No. 2, California State Mining Bureau. Dr. J. J. Crawford, State Mineralogist.

TUNNELS AND DRIFTS.

The methods employed to sustain the roof and sides of tunnels and drifts are numerous, the existing conditions determining the method. Often the rock is sufficiently firm to stand without timber, but at times the conditions are annoying and dangerous.

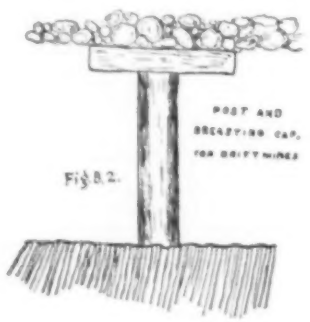


Where the pressure is entirely overhead, an upright post is set on either side of the tunnel, usually spread somewhat at the bottom, but otherwise always at right angles to the roof. (Drifts are frequently run on an incline, particularly in blanket veins, and also in fissures having a low angle of dip.) (See Figs. 2 and 4.) On these posts are placed a cross piece called a cap.

When it may occur that the floor of a tunnel, drift, or cross-cut does not afford a firm foundation for the posts, as in soft, wet fissures, when not in ore, or as is often the case at the entrance to a mine, a cross piece or sill is first laid and the posts set upon it. A second cross piece (the cap) is then inserted at the top, the ends resting upon the posts, the cap being employed in all cases, whether the sill is necessary or not.

In working ground that is fairly firm, particularly in the drift gravel mines of California, a system of posts and "breasting caps" is used. This consists of a piece of timber, hewn or split, 2½ feet long, 1 foot wide, and 3 or 4 inches in thickness (the cap), which is placed against the roof, and a post of the necessary length is set beneath it, being driven into a perpendicular position by blows of a heavy hammer or maul. It is a cheap and secure method of timbering small drifts, and is often employed in large ones, the breast extending entirely across the channel. Lagging placed at right angles to the cap may be driven in above it when necessary.

Very often pressure is exerted from the sides as well as from the top of a drift. In such cases the timbers



are framed with a view to binding them more firmly together when in place. (Fig. 8.)

Figs. 1, 2, 3 and 4 show several styles of framing timbers for drifts. Of these, Fig. 4 is undoubtedly the best. Better than any of these is the beveled notch, which greatly reduces the liability of the timbers splitting. It has come quite extensively into use of late years. When properly framed and set there is little danger of slipping. Still another, and no doubt the best method of all, has lately come into practice. It is that of nailing a two-inch plank on the under side of the cap. By this device the full strength of the timbers is obtained, with no probability of splitting.

When round timbers are used they should always be stripped of the bark or they will speedily decay. The manner of framing timbers is the same, whether they be round, hewn or sawed.

Figs. 5 and 6 show a method of placing posts and caps. It is seldom seen now. There is nothing about it to recommend it. Oak is the only timber that may be safely employed in this manner, pine being too soft and quite certain to split.

Where one side of a drift only and the roof need support, the post and cap (Fig. 7) is sometimes employed. One end of the cap rests upon the post and the other half on a shelf or niche cut in the opposite wall.

LAGGING.

When the roof or side of a tunnel is loose and shows any tendency to cave, sprawl off or run, lagging must be employed. Lagging is the name given to strips of wood 4 to 6 feet long, 6 to 8 inches wide and 2 to 2½ inches thick. They are usually split from pine logs, but sometimes 2-inch plank 6 inches in width is substituted. In large shafts in heavy ground 3-inch plank is sometimes employed. The methods of driving lagging are shown in Figs. 10 and 12. The pieces of lagging are inserted over the top of the cap, the ends pointed upward a few degrees. They are driven forward as the work of excavation progresses, when there is danger of caving. Not infrequently ground will stand for many hours and sometimes for months before caving, but it is cheaper to timber very soon after the excavation has been made, in order to keep the ground in normal condition, giving it no chance.

The two systems shown in Figs. 10 and 12, while the same in principle, differ materially in detail. In Fig. 10 the lagging is inserted between two caps, which are separated by wedge-shaped blocks, one of which is placed in the center and one at either end. (See between A and C, Fig. 11.) The lagging is driven forward as explained. If the ground is very heavy, a "false set" (Fig. 12) is set up and the ends of the lagging rest upon it. The excavation progressing and the lagging being driven well forward, the next set is put in position and the lagging driven "home," that is, until the forward ends find a secure resting place on the true set. The false set is then knocked out and the same procedure gone through with the next set.

The only difference between Fig. 10 and Fig. 12 is that in the former there are two caps, as explained above, while in Fig. 12 the lagging is inserted beneath the forward ends of the next set back. In each case the lagging is kept pointed slightly upward by the insertion of a block of wood shown at B, Fig. 12. When the forward ends of the lagging rest on the false set, this block may be allowed to drop out. The system shown in Fig. 10 can be employed more advantageously and work progress more rapidly in very heavy ground than when that shown in Fig. 12 is used, which does very well in lighter ground. Where the ground is very bad the lagging must be driven as far forward as possible. By observing care in this matter serious runs are sometimes prevented. Sills are only employed when the bottom of the tunnel does not afford a firm foundation for the posts.

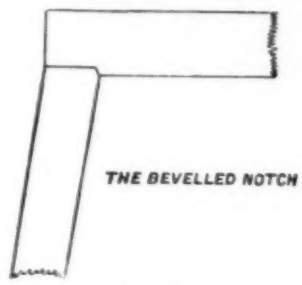


FIG. 9A.

For lagging, spruce, yellow pine, and tamarack are much used, but the sugar pine of California has no superior for toughness and durability. Lagging should not be too strong, for in the event of extreme weight it should bend and give notice of impending danger. The miner may then relieve the pressure by cutting away a portion and re-enforcing the timbers, thus saving the more expensive framed timbers and perhaps preventing a serious cave.

Caps and posts are all sizes from 4 × 4 or 4 × 6 in. up to 24 × 30 in., according to the size of the excavation and the character of the ground. Caps should be free from knots and checks as far as possible. Less care is necessary in the selection of posts, though all timbers should be of good, sound wood. Sills extend somewhat beyond the posts which rest upon them. A shallow notch is usually cut in the sill to admit the

post, the bottom of which is cut at right angles to its sides. (See Fig. 13 A.)

The greater care taken in framing and setting up mine timbers, the less danger there will be of collapse in the future. The tools necessary to secure this exactness are a plumb bob and a steel square. A spirit level is also very useful.

TRACK LAYING.

To construct a track, cross ties, made of 3 × 4 scantling, are often laid on the floor of the tunnel or drift,

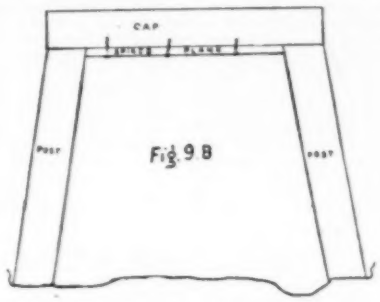


Fig. 9 B

and to these are spiked "T" rails. When flat iron is preferred, a durable track for permanent use is made by setting long 2 × 4 scantling in slots sawed in the cross ties, the long strips being secured by driving in wedges at the side. The details of track construction are shown in Figs. A, A1, A2, A3, and A4, which are on the same plate as Figs. 1 to 9. Upon the scantling stringers may be spiked the flat iron, or if desired, "T" rail. The scantling should not be spiked to the cross ties, as nails are quickly corroded by the mineral vapors and waters of mines.

DRAINAGE.

Provision for drainage should always be made at the very commencement of opening a mine, for, though

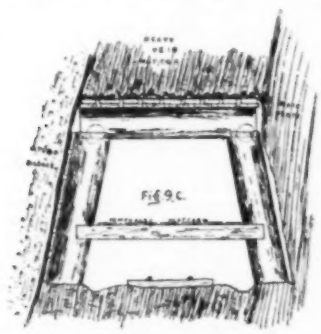


Fig. 9 C.

the tunnel may be dry at its mouth, when it has been driven a long way into the mountain more or less water is nearly always encountered. A drain or trench should always be cut in the center or at the sides of every tunnel or drift. Ill drained workings cause the timbers to rot quickly, and also endanger the health of the miners. Neglect to provide drainage very often results in the necessity of retimbering, which expense might otherwise have been avoided for a long time.

Prospectors in their haste to advance work as speedily and as cheaply as possible frequently fail to timber properly and to provide for drainage, with disastrous results in the future. Many months of laborious toil are too often lost in this way, to say nothing of the loss of life and limb by the unfortunate miner caught in a cave, which might have been easily avoided.

SWELLING GROUND.

One of the greatest difficulties with which miners have to contend is the swelling of the rock masses into which their excavations have penetrated. Often the force of pressure against timbers caused by the swelling of the ground is irresistible. It is a common feature of many of the Mother Lode mines in California, particularly in Tuolumne, Calaveras and Amador counties. Swelling bedrock is quite common in the gravel drift mines of California. All Comstock miners know what swelling ground is. It is one of the most serious obstacles with which they have to contend.

In a general way it may be said that the only recourse is to timber in the most substantial manner, and then by frequently, or as often as necessary, cutting out a portion of the heavy ground and relieving the pressure the timbers may be kept in place and the excavation kept open. Fig. 14 represents a cross section of a tunnel where this trouble in its worst form was encountered. By setting timbers in the manner shown in the cut, placing the sets close together, and relieving the ground by the removal of the encroaching portion from time to time, the trouble is reduced to a minimum. In the Hardenburg Mine, Amador County, swelling ground has caused a great deal of trouble lately. The 900 foot level is run in a zone of crushed foliated black slate, which, on the foot-wall side of the drift, when first broken, appears firm and solid, but in a few days it commences to spawl off and to noticeably encroach upon the drift. It continues to swell, displacing timbers or breaking them, and causing no end of trouble. Now such places are timbered with 18 and 20 inch round timber and somewhat loosely lagged. But few days pass before it is necessary to take out lagging and cut away the swelled ground.

In running the main tunnel of the Hidden Treasure

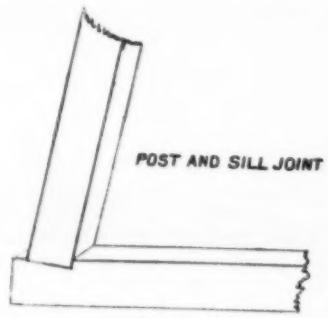


Fig. 13 A.

Mine at Forest Hill, in Placer County, swelling bedrock was encountered. Mr. Ross E. Browne, E.M., in his article, "The ancient river beds of the Forest Hill Divide" (vide X report, State Mineralogist of California), says of this occurrence:

"The pressure of the gravel is not great, but the swelling bedrock has been a source of trouble, driving the legs of the timber set inward and crushing the cap. After many unsuccessful attempts to overcome this difficulty, the legs were given an increasingly greater bottom spread, until finally it was found that they remained stationary. The swelling bedrock is removed from time to time and the track adjusted. The accompanying cut shows the form of tunnel timber set now used in bad swelling ground. Sets are first put in 4 feet apart, and in the course of a few months center sets are placed between these. Timber sets on this plan have now been in place three years (1879), and are still in good condition. In 8,500 feet length of tunnel there are about 4,000 sets of timbers. Two men are kept constantly employed in easing and repairing the sets and adjusting the track."

Some of the drift mines on Sugar Loaf Mountain, near Nevada City, Cal., that were worked twenty-five years ago, were timbered in a very peculiar and unusual manner, owing to the swelling of the bedrock. Massive timbers had been placed time and again, only to be forced out of place or broken. At last the method here described was introduced and found to answer every requirement most admirably. It was subsequently tried in some of the other mines of the neighborhood with equally satisfactory results. Once firmly placed, the timbers were never again renewed, standing until the mine was worked out.

The plan adopted was as follows: A drift of the usual form was run and heavily timbered, being well lagged overhead. The sets were placed five feet from center to center. As the work of excavating the drift proceeded, a triangular section was cut out of each side of the drift between the posts of the two adjoining sets. These two posts formed the base of the triangle, the apex being directly opposite the center of the base. At the apex a post was set, the center of which was three feet from the center line of the posts forming the base. Caps were placed, reaching from the post at the apex to each of those of the base, and lagging driven in diagonally from the drift. The two sides of the triangular section opposite the base were lagged, a considerable space being left between the lagging to afford an opportunity for the soft swelling ground to force its way through the open spaces, when it is removed. These triangular spaces were continuous; that is, were cut opposite each set of the main drift. The method involved considerable extra expense in mining and

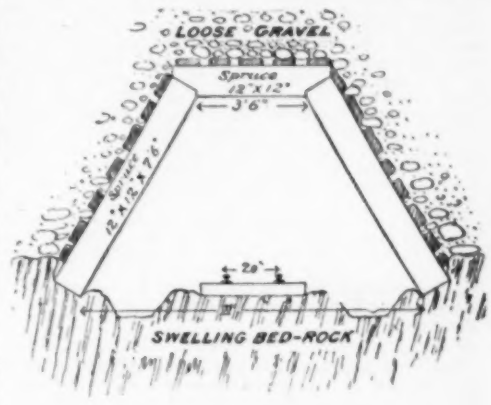


FIG. 14.

timbering, but it was so infinitely superior to any plan previously tried that it was looked upon as a success mechanically and financially. The accompanying sketch will make plain the details of this peculiar method, which, since its use on Sugar Loaf Mountain, seems to have been lost sight of.

Drifts sometimes require but a few posts to support particular rock masses that threaten to fall. Where a post alone affords insufficient support, a heavy piece of plank (plate) is inserted between the top of the post and the roof.

RUNNING GROUND.

Tunnels and shafts at times must pass through soft, running ground. Zones of rock of this description are often found lying between walls of firmer rock. The occurrence is not infrequent on the Mother Lode of California when the fissure is barren of quartz and filled with a mass of soft crushed foliated black slate. It is prominent in the Quaker City, Gwin, Hardenburg, Kennedy, and many other mines on the lode. Such ground is nearly always wet, and the process of sinking or drifting in it is attended with expense and danger. In sinking through such ground the miners usually make an effort to push the work and pass through it as quickly as possible. When the ground is very wet and runs easily it is not always the best plan to "crowd" it. In some cases the difficulties are more easily overcome, the expense reduced, and the completion of the task sooner accomplished by going slowly, allowing the ground to assume a more normal condition by cutting out and removing the material falling into or forced into the excavation. When water is troublesome in ground of this character, the better plan is to permit it to drain off. By so doing the ground sometimes becomes firmer, and, as a consequence, is more easily handled, timbers more readily placed in position, and the work carried on more satisfactorily.

Another kind of ground difficult to timber is found

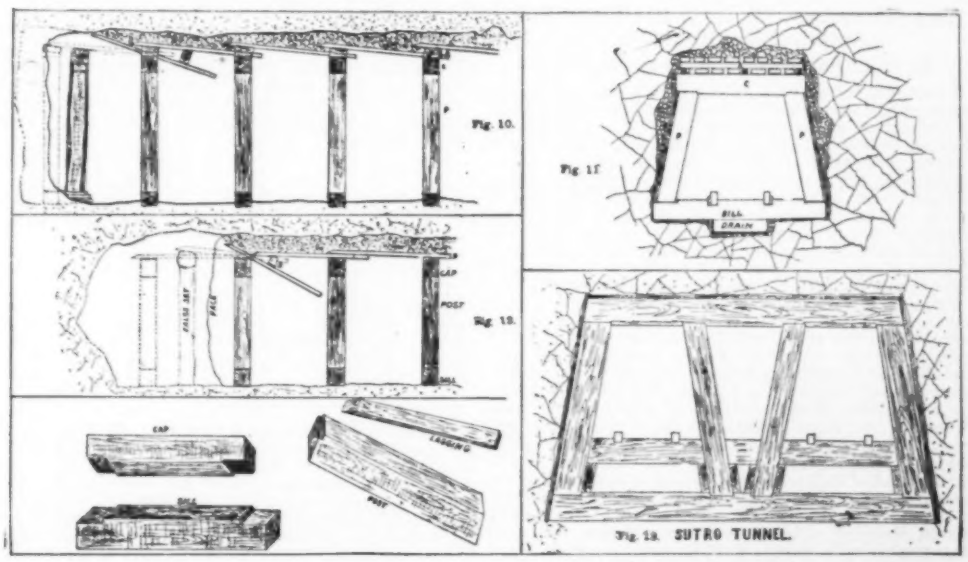


Fig. 12. SUTRO TUNNEL.

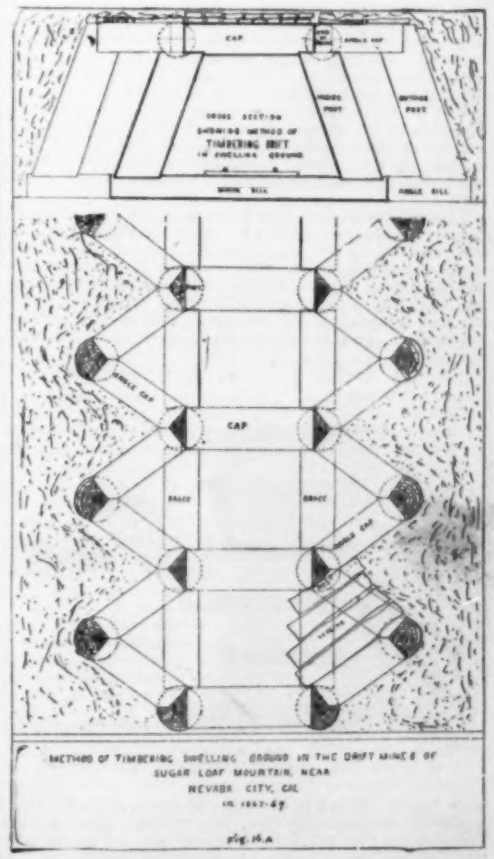


Fig. 14 A.

in some much altered rocks where talc, steatite (soapstone), and serpentine, containing much water, have to be passed through. The ground often breaks well and sometimes stands well for a time, but it is treacherous and should be promptly and substantially timbered. Rocks of this description are abundant in the great auriferous belt of California, and as miners there well know, are usually fissured in every direction and upon exposure to the atmosphere exhibit a tendency to break up (called blocky ground). Great angular blocks and "heads" (round bowlders) drop from the roof and sides without warning. The former are often wedge shaped and slip out from the fissured rocks when the ground had appeared firm and solid. The heads are usually hard in the center, while the outer portion is quite soft, feeling greasy to the touch. In size these masses range from an inch or two in diameter to those which weigh tons. Timber must be placed in ground like this immediately as the work progresses. The sets should not be more than $2\frac{1}{2}$ feet from center to center, instead of the usual distance, 4 to 5 feet, whether it be in shaft or tunnel. Lagging, when used, must also be short.

When passing through slips or fissures, whether single or in zones, in any kind of rock, extraordinary precautions should be taken, as accident is much more likely to occur at such points than in solid, unfissured ground. Rock in the vicinity of veins is nearly always more dangerous that that at a distance from the vein.

SHAFTS.

Working shafts, as well as tunnels and drifts, should be arranged with a view to securing their permanency. Indeed, in consideration of future possibilities, even greater care should be exercised in the selection of their location and in deciding upon their size, while the manner of timbering is most important. Working shafts should be so equipped as to remain open and be in use as long as ore remains in the mine which it will pay to extract. As in all other mine work, the amount of timber required depends largely on the size of the shaft, and more particularly on the character of the rock through which it passes. Prospecting shafts are sometimes sunk in good standing ground to the depth of several hundred feet without other timber than a few stulls, to which ladders are secured. The few timbers thus placed often become insecure through neglect, particularly in regions where there are climatic alternations of wet and dry. When wet, the timbers and the wedges securing them swell. With the change to dryness they shrink and are likely to drop out. An additional danger results when the rock walls crumble, and men working below are in constant danger from falling rocks and timbers. The wedges demand frequent attention, for they must be kept driven well in at all times. On the desert and in mines above timber line, where timber is expensive, miners endeavor to get along with as little as possible and are not very particular as to the kind and quality of that which is used. It would perhaps be a better plan to dispense with timber altogether than to place too much dependence on sticks that are likely to drop out of position unexpectedly. As a matter of fact, the writer has seen shafts in the Mojave Desert mines more than 300 feet in depth without a single stick of timber. The necessities of the case in sparsely timbered regions and on the desert have obliged the miner to resort to many novel plans to protect himself against danger at the least possible expense. He puts in as substantial a frame of timbers as he can obtain, or he may think he can afford, using a few frail saplings, thin, split lagging, or even brush, to support the sides of his shaft. Fortunately for him, in the desert regions, where scarcity of timber forces upon him this economical "system" of timbering, the rock, being nearly always dry, stands fairly well, as a rule, and expensive timbering is not necessary.

The extremities to which prospectors are often reduced to procure timber in these timberless regions has resulted in the adoption of a method peculiar to such districts. While the result is not particularly pleasing from a workmanlike standpoint, it nevertheless exemplifies most faithfully those principles which are the foundation of the most elaborate system of timbering. In these shafts all timbers are stulls, each

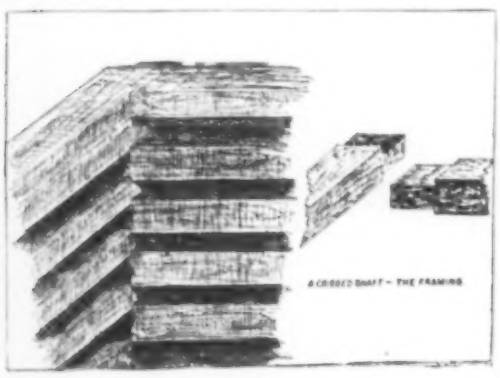


FIG. 14B.

one being placed to support some particular rock or mass which seemingly threatens to fall. Each stick is independent of the others; there are no superfluous timbers, and no attempt at system or regularity. As a result these sticks cross the shaft at many angles. Some are horizontal, but most of them inclined somewhat from that position. It sometimes gives the shaft timbers a spiral appearance as viewed from above. Despite the fact that these timbers are placed so much at variance with recognized methods, if placed at the time of making the excavation, or shortly thereafter, and are properly and firmly wedged, they usually render the shaft fairly safe. In that region old redwood railroad ties are very frequently used for mine timbers, and answer admirably, even though unsuited for such use from having lain for months in a railroad bed, being split and often cut by the rails. The miners are glad to get them, poor as the timber is, for when once properly placed they have been found to do very well, where the pressure is not too great.

Shafts having a single compartment, such as are frequently seen in small mines, are timbered in a simpler manner. The timbers consist of two wall and two end plates and four posts to each set. The method shown in Fig. 14 C is quite common and suited to shafts of moderate size (5×7 in the clear) having a single compartment. The four frame timbers are placed in position and tightly wedged, the posts being driven in at the corners. Care must be taken to keep the sets in line. Sets are ordinarily five feet apart from center to center. When the ground is heavy, sets may be placed closer than five feet. They are often only half that distance from center to center.

Lagging, either split or sawed (2-inch plank), is driven in behind the timbers. It is driven one-half to three-quarters of the way down, when the lower ends of the next set below are inserted between the timber

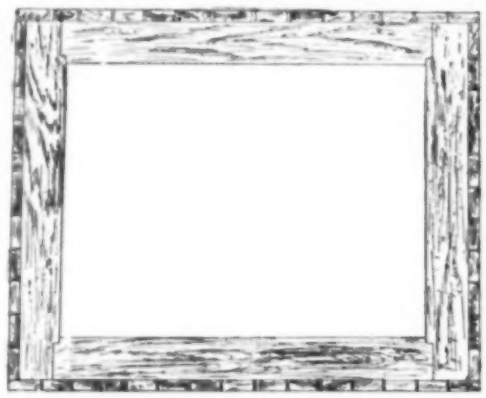


FIG. 14C.

and the wall. Later the lagging of the set above is driven down to its proper place.

CRIBBED SHAFT.

When the pressure of the ground is very heavy, a crib of timbers is built, the timbers being placed one on another with only a notch at the ends to hold them in place. In soft ground it may be necessary to use lagging, even in a cribbed shaft. All open spaces between the walls and the crib or lagging should be filled with broken rock to secure firmness, and to counteract any tendency of the timbers to shift. The manner of framing crib timbers is shown in Fig. 14B.

REACHERS IN SHAFTS.

When sinking can be carried on somewhat in advance of timbering, it is sometimes the custom, in firm ground, to place long timbers, called "reachers," across the shaft, the ends resting in niches cut in the walls. These having been firmly placed, the four timbers of the set are laid upon them and firmly wedged, and from this foundation the sets are built upward to the next set of "reachers" above, a distance of twenty-five to thirty feet. Where the shaft is sunk in country rock, or in a large pillar of ore (the latter to be avoided when possible), the "reachers" are placed alternately in sets at right angles.

The manner of framing the ends of shaft timbers where they join at the corners is shown in the cuts of the Requa, Forman, and Alma shafts and the Argonaut incline.

Men working in shafts placing timbers usually work suspended on slings secured to timbers above.

(To be continued.)

THE GENERATION OF CHLORINE FOR LABORATORY PURPOSES.*

By F. A. GOOCH and D. ALBERT KREIDER.

THAT chlorine may be generated in a state of greater or less purity, variable with the conditions of evolution, by the action of hydrochloric acid upon potassium chlorate has been shown by Pebal† and Schacherl,‡ but the application of this fact to the practical generation of chlorine for the purposes of the laboratory has not, to our knowledge, been proposed. The desirability of an automatic generator from which an abundant flow of chlorine gas may be drawn at will or shut off without danger or inconvenience has led us to a study of the conditions most favorable to the safe evolution of chlorine by the action of the chlorate.

Pebal§ showed that the gas evolved at ordinary temperatures from a mixture of potassium chlorate and sodium chloride acted upon by sulphuric acid, diluted with twice its volume of water, consists of chlorine and chlorine dioxide in nearly equal proportions. Schacherl‖ found that when potassium chlorate was acted upon by hydrochloric acid diluted with twice its own volume of water the yield of chlorine was about 46 per cent. or 57 per cent. of the mixed gases, according as the chlorate was granular or in fine powder; that hydrochloric acid of half strength yielded a gas containing nearly 60 per cent. of chlorine, and that the proportion of chlorine rose nearly to 68 per cent. when the gas was passed through concentrated hydrochloric acid and then washed with water; that the chlorate when acted upon by the strongest hydrochloric acid cooled to 0° C. and then warmed only enough to start the action yielded a gas carrying 87 per cent. of chlorine; and that when a solution of potassium chlorate was permitted to flow into hot strong hydrochloric acid the free chlorine constituted nearly 75 per cent. of the mixture. So it appears that the highest yield of chlorine resulted when the solution of the chlorate entered gradually the hot strong acid—a condition not easily attained in an automatic generator.

The fact that chlorine dioxide is so easily decomposed by heat into chlorine and oxygen naturally suggests the possibility of increasing the proportion of chlorine evolved in the first instance by working at the highest temperatures practically attainable under the conditions. In order, however, to secure a temperature approaching the boiling point of water it is necessary to reduce somewhat the strength of the hydrochloric acid acting (in order to avoid the evolution of hydrochloric acid gas and the consequent interference with the regular automatic action of the generator), thus sacrificing the advantage naturally attending the use of acid of the highest degree of concentration. Upon experiment we find that acid of half strength (sp. gr. 1·10) can be made to yield a very satisfactory proportion of chlorine. We have employed in our work potassium chlorate fused (best in platinum) and cast in sticks or broken into coarse lumps. A small Kipp's apparatus, holding about a half liter of liquid in the two lower chambers, makes a convenient generator, and the requisite temperature may be secured by wrapping the two lower chambers with flexible metallic tubing through which steam is driven, or, with equal convenience, by simply standing the whole apparatus in heated water. When the simple precaution is taken to heat the acid to 60° or 70° C. before allowing it to come slowly into contact with the fused chlorate, no difficulty whatever is met with in the practical automatic working of the generator; but if cold acid is permitted to act upon the chlorate, it becomes charged more or less with the chlorine dioxide, and a subsequent rise of temperature may cause dissociation of the explosive gas with sufficient suddenness to expel the liquid from the generator with considerable violence. The gas evolved directly from the generator is never pure chlorine. To determine the relative proportions of chlorine and chlorine dioxide (the sole products of the action according to Pebal) the gas as it issued from the generator was passed through two pipettes fitted with glass stopcocks and joined to one another. After allowing a reasonable time for the complete expulsion of air from the pipettes the stopcocks were closed and the pipettes were disconnected from one another and from the generator. The gas contained in one of the pipettes was slowly forced by means of carbon dioxide through a solution of potassium iodide; that in the second pipette was driven slowly by means of carbon dioxide through a hard glass tube filled with asbestos and heated to redness by a Bunsen burner, and then passed through a solution of potassium iodide. The iodine set free in each case was determined in the acidified solution by standard sodium thiosulphate, and the difference in the amounts of iodine found was attributed to the action of the oxygen of the chlorine dioxide. It was assumed that the gas filling the pipettes ranged in line was homogeneously distributed, and this assumption is probably nearly enough true for the purpose of this discussion. The temperature of the acid in the generator was determined by inserting a thermometer in the lowest chamber of the generator, so that the indication for the point of action is only approximate.

In two experiments made with acid of half strength and at indicated temperatures of 80° and 81° the chlorine in the gas amounted to 81·6 per cent. and 84 per cent., respectively, of the mixture. A comparison experiment made with the strongest acid heated to 50° – the highest temperature attainable without evolution of the hydrochloric acid gas—the yield of chlorine was 77·3 per cent. It is evident that the acid of half strength acting at 80° is productive of a more favorable yield than the strongest acid at 50°.

Temperatures very much higher than those employed can hardly be secured continually under the conditions of work, and yet it is plain that a considerable amount of the oxide still accompanied the chlorine. We made the attempt, therefore, to accomplish the destruction of the oxide by passing the mixed gases as they issued from the generator through a small wash bottle containing a hot saturated solution of manganous chloride in strong hydrochloric acid, making use of a device previously employed in this laboratory for the decomposition of nitric acid and chloric acid.*

The results of several experiments conducted in this manner are recorded in the accompanying statement. The gas, after leaving the manganous chloride, passed through a small wash bottle filled with water, was dried by calcium chloride, and collected in the pipettes arranged in train, and analyzed by the method previously described.

Strength of Hydrochloric Acid.	Temperature of Acid.	Temperature of the Solution of $MnCl_2$.	Bubbles of Gas Passing the Wash Bottle per Second.	Per cent. of Chlorine.
Sp. gr. 1·1	83°	90°	5–6	87·5
" 1·1	83	90	4–6	89·5
" 1·1	70–80°	90	1–2	96·4
" 1·1	87·5	90	3	98·6
" 1·1	83	90	3	96·9

It is evident from these figures that the efficiency of the manganous chloride is considerable, and naturally most manifest when the current of gas is slow. Indeed, during the passage of gas through the manganous salt small bubbles of chlorine are evolved from the entire surface of the liquid. The washed gas is pure enough for most laboratory purposes, but if chlorine perfectly free from chlorine oxide is desired, it may be obtained by passing the washed gas through a hard glass tube filled with asbestos and heated by a Bunsen flame.

In the exceptional cases in which the ignition tube is used it is well to keep in mind the fact that in starting the generator the acid should not be thrown in too great quantity upon the chlorate at first, lest an unusually large proportion of the dioxide be liberated, which may cause a slight explosion in the ignition tube. Should such be the case, however, the liquid in the wash bottle will prevent the extension of the

* Contributions from the Kent Chemical Laboratory of Yale College.

† Ann. der Chem., clxxvii, 1.

‡ Ibid., clxxxii, 197.

§ Loc. cit.

‖ Loc. cit.

* This journal, xliv., 117; xlvi., 231.

explosion to the gas in the generator proper, and the insertion of the wash bottle should never be omitted when the ignition tube is to be put to use. So long as it is kept hot we have never found the apparatus other than perfectly manageable, safe and automatic in action.

Inasmuch as a single gramme of potassium chlorate produces approximately a half liter of chlorine and a cubic centimeter more than a liter, it is obvious that a very compact generator may be capable of delivering a considerable supply of the gas, and we have found the diminutive apparatus shown in the accompanying figure an exceedingly convenient addition to

the furnishings of the laboratory table when chlorine is needed frequently and in small amounts. This little generator is easily made of a side-neck test tube, funnel tube, stopper, glass stopcock and flask. The upper chamber of the test tube, which is constricted near the middle, holds easily ten grammes of the fused chlorate, and when the outer flask is filled with hot water the automatic action is satisfactory for a considerable length of time. A little wash bottle containing a hot saturated solution of manganous chloride in strong hydrochloric acid is a desirable addition when a purer gas is needed than that delivered directly from the generator, and the attachment of the ignition tube makes it possible to secure the chlorine entirely free from chlorine oxide, though carrying, of course, some free oxygen.—Amer. Jour. Science.

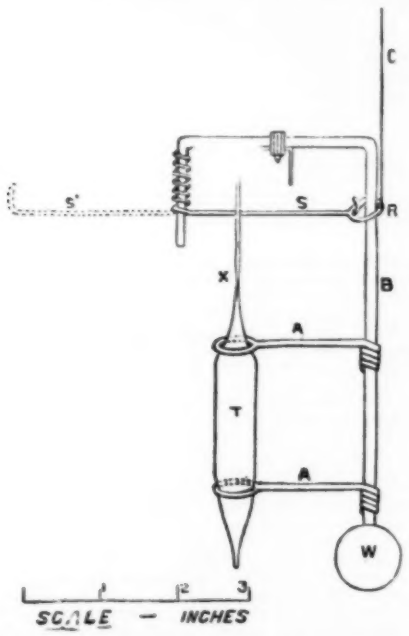
APPARATUS FOR COLLECTING SAMPLES OF WATER SOME DISTANCE BENEATH THE SURFACE.

By WILLIAM T. BURGESS, F.I.C.

IN the present state of knowledge it is frequently necessary for chemists to supplement the chemical analysis of a water by a bacterioscopic examination, and for this purpose it is advisable to collect a small special sample with the greatest care.

I have occasion to collect a large number of samples for bacterioscopic examination under conditions where to obtain perfectly representative samples they must be taken several feet below the surface; for this purpose I have devised the little apparatus described below, and venture to think it an improvement on the arrangements illustrated in various works on bacteriology.

The sterile collecting tube, T, having a capacity of about 6 c. c., is drawn out at each end, the longer end being further drawn down at x to a very fine capillary, so that a slight blow near the end causes it to break off at that point. The tube is only partially exhausted, and this is conveniently effected by heating the body



of the tube and sealing up while still hot. (A stock of sterile tubes is stored in small cylindrical metal cases.) The tube is supported by two hard brass wire arms, A A, adjustable on a stout brass wire, B, which is bent twice at right angles. One end of this wire carries a weight, W, and the other a helical spring, S, made of piano wire. The normal position of the free end of this spring is shown at S', but before the tube is placed in position it is brought over to the other side and retained by a loose ring, R, attached to the wire, C, by which the apparatus is lowered. The spring is sufficiently strong to carry the apparatus without slipping out of the ring if it is lowered into the water carefully, but a slight jerk is sufficient to release it, when it flies round and breaks off the end of the exhausted tube at x. The tube fills in a few seconds, when it may be drawn up, sealed, and stored with the usual precautions until the cultivations are started.

Several of these contrivances may be arranged on one wire, and thus a number of samples at definite depths may be collected simultaneously; and by constructing the apparatus of stouter materials it may be employed for taking larger samples.

Having experienced the convenience of this little device, which is manipulated by a single wire, I hope this description may be of use to other chemists.—Chemical News.

AN IMPROVED COMPOUND FOR USE IN THE MANUFACTURE OF MATCHES.

By H. PRIESTER, Lauenburg, Pomerania.

CLAIMS "the utilization of magnesium either alone or alloyed with other metals to form combustible compounds capable of being applied by dipping," matches coated in this way giving a colored light and scattering sparks when burning. It is stated that a much more brilliant result is obtained when the magnesium is alloyed with copper, cadmium or zinc, and then added to one of the known firing mixtures.

SOME LABORATORY APPARATUS.

By A. BIDET. Comptes Rend.

Siphon Level Regulation.—This is an S-shaped tube (Fig. 1) with a side tube S sealed on a little above the

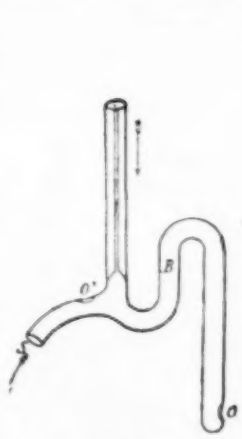


FIG. 1.

FIG. 2.

lower bend. The long arm, O, is inserted in the apparatus in which the constant level of liquid is required, and the hole, O, is placed at the side of the tube to prevent air from the boiling water passing up into the siphon tube. Water flows continuously through A, and may then pass through either S or B, the tube BO forming a siphon which may act in either direction according as the level of the water in the apparatus to be supplied is above or below that for which the instrument is regulated. The hole, O_1, by free admission of air, serves to prevent the tube, S, from acting as the limb of a siphon.

Safety Tube Arranged to Prevent Splashing.—This apparatus (Fig. 2) serves for introducing liquids into a vessel and for leading off gases by the side tube. Regurgitation quietly transfers the liquid in the middle cylinder into the upper funnel through the recurved tube at O, whence it returns after the pressure has again become normal. The lower tube is adapted to a tubulure by a cork with one perforation.

Internally Cooled Condenser.—In this instrument (Fig. 3) the vapors entering by the upper tube are con-

FIG. 3

densed in the annular space surrounding a water-cooled glass tube, sealed into an outer vessel at its lower end, and the condensed liquid passes away through T. An outside water jacket may be adapted to this, so that a double cooling surface is presented for condensation.

Commutating Arrangement for Condenser.—By connecting an inverted condenser with R (Fig. 4) and a downward condenser with D, and adjusting the inner circularly sliding tube, I, so that the hole, O, is opposite one or other of these tubes, this instrument allows distillation or cohobation to be carried on at will, or to be effected alternately without delay. The tubes are joined by an India rubber ring. A cork in the in-

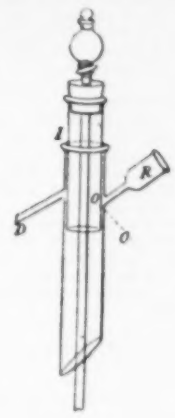


FIG. 4.

ner tube permits the passage of a separating funnel for the introduction of liquids into the distilling flask.

Superheater for Vapors.—The superheating is effected by passing the vapor through T (Fig. 5) to the copper spiral, which is inclosed in a brass jacket terminating above in an open cone. The spiral is lined with metallic gauze, and beneath it is placed a suitable burner. The superheated gases pass away over the bulb of a thermometer, t. With such an instrument

FIG. 5.

20 cm. high a temperature of 300° C. has been attained in the efflux. With a triple Bunsen burner a still higher temperature could be attained.

NOTES ON ALUMINUM.*

By GEORGE FREDERICK ANDREWS.

THE writer of this paper has made a large number of experiments with aluminum, particularly with reference to its use in jewelry, etc. The facts stated are the results of some of these experiments.

Alloys Containing Gold.—The alloys of gold and aluminum are interesting, though of little practical use except for decorative purposes. The alloy with 6 per cent. of gold is as white as pure aluminum, but much more brittle. The alloy with 10 per cent. of gold is harder than aluminum, but does not work well except at a high temperature. Its color is light violet brown. The alloy with 15 per cent. of gold is a very soft fine grained metal. It has a slight violet tint, although nearly white. The alloy with 50 per cent. of gold has a beautiful violet color. It is very soft and spongy. The alloy with 78 per cent. of gold is very brittle. The color is peculiar; it is between pink and violet. The alloy with 90 per cent. of gold has a pale violet color, while the alloy with 94 per cent. of gold has a color approaching pink again. Alloys containing small percentages of aluminum leave a bright violet color on the cupel, under the blowpipe.

An alloy containing 50 per cent. of gold, 45 per cent. of copper, and 5 per cent. of aluminum takes the color and polish of 14 carat gold, but easily tarnishes. This alloy has also been used in electroplating, but it is not entirely satisfactory for this purpose.

Alloys Containing Silver.—Alloys containing from 4 to 8 per cent. of silver and from 96 to 92 per cent. of aluminum are useful for many purposes. They are harder than aluminum but not brittle. They take a very fine polish, and hold it well. Their color is very near that of fine silver. These alloys are now used for the manufacture of charms, medals, metal trimmings and decorations of various kinds.

Alloys Containing Nickel.—The alloy containing 50 per cent. of nickel and 50 per cent. of aluminum has a dull gray color. It is very porous, and so brittle as to be useless.

The following alloys of copper, nickel, and aluminum are all very hard, fine grained, and show great strength. The alloy containing 66 per cent. of copper, 24 per cent. of nickel and 10 per cent. of aluminum takes a fine polish, and has the color of 10 carat gold. The alloy containing 55 per cent. of copper, 33 per cent. of nickel and 12 per cent. of aluminum has a beautiful golden brown color. The alloy containing 72½ per cent. of coper, 21¼ per cent. of nickel and 6¼ per cent. of aluminum closely resembles it, but the color of the latter is richer and deeper. These alloys may become very useful for decorative purposes.

Solder for Aluminum.—Notwithstanding the assertions which are still heard to the contrary, aluminum can be successfully soldered. The writer has used solder which makes a clean, perfectly firm joint, and

* Abstract from a paper read before the Rhode Island section, Feb. 15, 1894.—American Journal of Science.

is in every way satisfactory. It requires no "soldering fluid" and no soldering iron.

Melting of Aluminum.—In melting aluminum the temperature should be kept even, and not much above the melting point of the metal. The metal should be fed into the crucible in small pieces, and pushed down as fast as it becomes soft. The most serviceable flux is a little tallow, although it is not necessary to use any. A sand crucible must not be used, as the aluminum readily attacks the silicon.

In alloying, the aluminum should be put into the crucible after the other metal or metals have become liquid.

Restoration of the Mat.—Aluminum can be cleaned, and its peculiar mat restored by dipping for a minute and a quarter in a solution of three ounces caustic potash in a quart of water, then washing thoroughly and dipping in a mixture of three parts nitric and two parts sulphuric acid, by volume.

Caustic soda can be used with nearly as good results. The main advantage in the substitution is the lower price of caustic soda.

A GREAT COTTON MILL.

IN a recent number of Engineering an elaborate and interesting account is given of the great cotton mills of Richard Haworth & Co., Salford, Eng., from which we take the accompanying illustrations and the following particulars:

At the present time the works of the firm in Ordsall-lane are divided into three mills and a weaving department. The mills are known as the Egerton, the Tatton and the Throstle Nest Mills, but they form practically one factory, although Egerton and Tatton Mills are a few hundred feet distant from each other. The total number of hands at present employed by the firm in all departments is over 3,000. Many of these, of course, are women. The number of spindles in Messrs. Haworth's mills is 140,000, and in connection with this it must be remembered that the whole of the operations in connection with the preparation of cotton are carried out by this firm. The average produce per spindle per year of warp or weft would be 100 lb. nearly, so that the output from these mills reaches the total of 6,000 tons of manufactured cotton per year.

It is difficult to give an average of fabric that would be woven from this amount of warp and weft, as the conditions vary so widely in different materials, but if we suppose the whole of the produce were woven into average calico or long cloth, it would amount to about 30,000,000 square yards per annum.

The number of looms owned by the firm is 3,200; and these are of all descriptions, as will be more fully explained when we deal with the weaving sheds.

The works are lit throughout by electric light by means of incandescent lamps, of which there are no less than 3,500 in all departments. The generating plant consists of several engines driving six dynamos.

Lighting, warming and ventilation are points which all receive thorough attention in these works, and those who have known the cotton industry for many years past cannot but feel glad to see how much more is now done for the health and comfort of the operatives than was the case in times past. It may be stated in passing, however, that the late Richard Haworth was one of the pioneers in this movement, and though one of the most successful business men of his day, he never let considerations of profit stand in the way of what he considered his duty to those serving him, in whatever capacity they might have been engaged.

Richard Haworth commenced life in a very humble way. He was, in every sense of the term, a self-made man, of a type which this country has always been exceptionally fortunate in producing; and doubtless the privations he went through in his early days caused him to sympathize with those in a like position to that which he had occupied, but who had not his exceptional talents to enable them to rise above the rank in which they were born. The good he did still remains, and the traditions of the firm are still worthily followed up. Certainly the people of Lancashire owe much to the small group of large-hearted, thoughtful men of whom Richard Haworth was a very active member. The confined atmosphere of the old time cotton mill and the physically trying operations of cotton spinning were fast leading to a degeneracy of the operatives which was tending to serious degradation of the race. In any case the mill hand can never hope to equal in physical development those who are engaged in outdoor pursuits, and the increase in the number of factory operatives, more especially among women, is one of the most serious problems of the age, and the chief set-off against the advantages of advanced civilization. Much, however, can be done by light and fresh air to improve the hygienic conditions of the factory; and those who, like the past and present managers of the mills now under notice, do their best in this direction, earn the gratitude of every class, for what affects one affects all. A detail which tells much of the attention paid to the comfort of the hands is a stool provided for the attendant to rest upon when not required to attend to the machine. To women this small boon is especially grateful. Only those who have spent a long working day afoot can appreciate the value of this small concession.

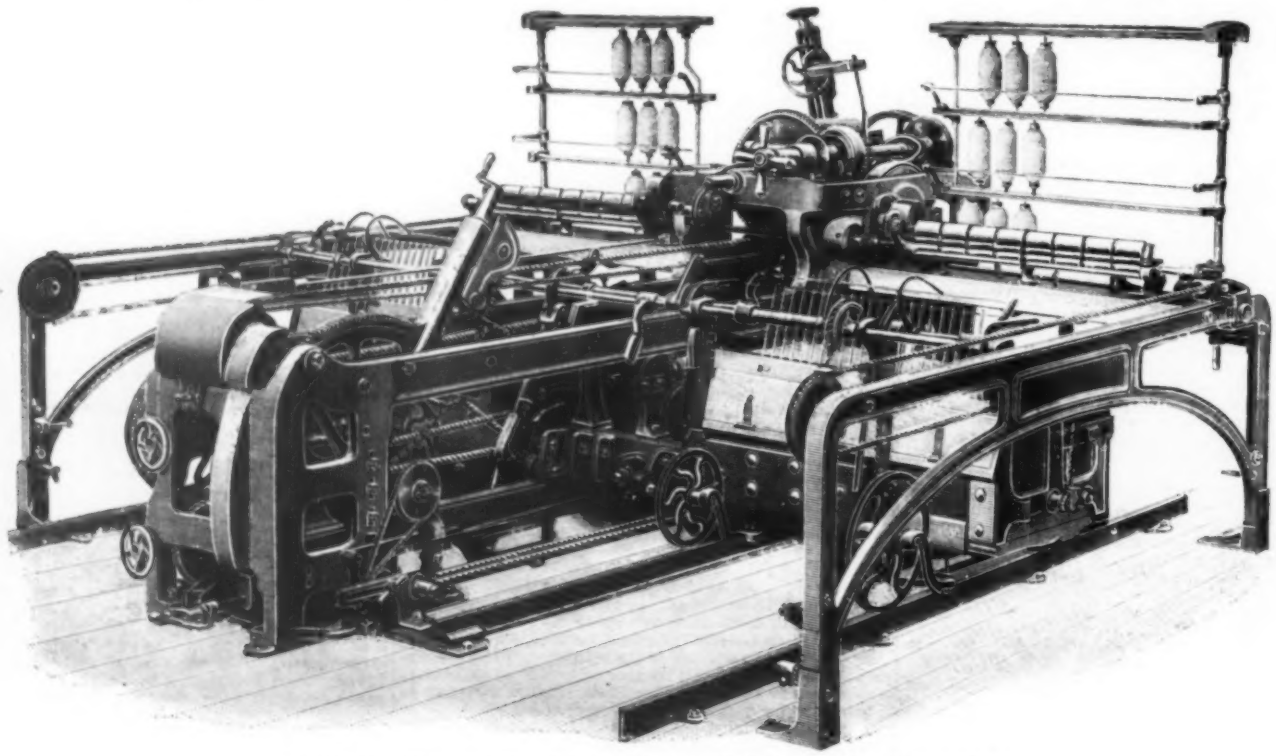
Even to those most accustomed to the marvels wrought by modern engineering, a cotton mill must always be a wonderful thing. If one counts a large steamship—either an armor-clad, such as the Royal Sovereign, or an Atlantic liner, such as the Campania—the noblest creation of the engineer, the cotton mill will not rank far behind. The steamship impresses by the magnitude of its parts, but the cotton mill almost stuns one's imagination by the endless multiplication of its diminutive constituents. Each of the thousands of spindles in a mule or ring frame is an engine in itself, driven from one central source, but doing a separate operation, which within a period that is historically but a few years ago would have taken the whole energies of one person. This, however, does not tell the whole tale, for not only does one spindle represent one operator, but it will do the work with an accuracy and rapidity that could never be approached by the spinner even with the help of the primitive hand-driven machines.

In order to effect this substitution of mechanism for human labor, the highest intellectual effort must be exercised in the production of the machines. The hand spinner could watch for and correct mishaps that would arise in the progress of the work, but machinery can exercise no such controlling power. It is necessary, therefore, that its operations shall be absolute, and this can only be obtained by an undeviating accuracy of movement and the insuring of an undeviating supply of regular material. The latter feature is secured by splitting the initial processes up into a number of stages, and depending on the averaging effect of oft-repeated doublings and drawings in the manner hereafter described. The excessively high speed at which the machinery runs and the absolute certainty of its movement afford results only obtained by complicated trains of highly ingenious mechanism manufactured with a regard to truth that is little less than marvelous. It is the old story of a principle which dominates the evolution of the factory system, the highest brain-work of a few original thinkers supplanting the skill of the operatives. In engineering practice the hammer, chisel and file are the most simple and primitive tools. There is no mystery about them, and their production is a simple matter. To produce a flat surface by their aid alone requires an amount of skill only to be obtained by long practice; but the planing machine is invented, and the surface is cut with accuracy by mechanical means. So it is in cotton spinning. The skill required by the operator to produce an even thread is no longer necessary; the burden is taken by the machine. The sinking of brain capital by the inventor bears interest for all time, and the consumer shares in the benefit of what some would call "unearned increment," were we to push our simile home. Were we to revert to the methods of production of a hundred years ago, four-fifths of clothed humanity would go all but naked.

It is satisfactory to know that the operatives share in these benefits also. We have already spoken of the danger of physical deterioration that may arise from the crowding together of workers in factories, but we referred to the mill hand as compared to the open-air worker; in comparison with his forerunner—the worker in the cottage industry—his lot is immensely improved. The spinner and weaver who worked in his or her own home had a life of almost constant toil, working often from the hour of rising to the time of going to bed, with but short intervals for meals.

The process of the manufacture of cotton as carried out in Messrs. Haworth's works may be taken as an example of a modern well-arranged cotton mill of the best type.

The cotton as it comes from the warehouse is brought to a room where it is examined, and the different qualities or descriptions are sorted according to the grades that may be required. Great care is required in this part of the work, as the cotton has to be selected to be suitable to the class of work it is to produce. For instance, rough, long staple cotton will be required for warp or twist, while the more silky fiber will be suitable for weft. Formerly, when the bales were opened the cotton was distributed by hand, the men going to the bins and scattering the cotton in handfuls, so as to mix it well up. It should be understood that for the production of warp or weft different descriptions of cotton have to be mixed together. A grade that will give the required qualities in one direction has to be used with another description of cotton that possesses other necessary characteristics.



FRONT VIEW OF MULE HEADSTOCK WITH PART OF CARRIAGE.

RICHARD HAWORTH & CO.'S COTTON MILL.

The first machine used is that known as a bale breaker. This machine consists of a suitable receptacle fed by an endless creeper formed by wooden slats mounted on endless bands. The cotton is put on to the creeper by hand, and is then carried to three sets of toothed rollers and one set of fluted rollers, which revolve at different speeds; the first pair running more slowly than the next, while the last pair have the quickest motion. In this way the cotton is opened out, and from the rollers it is taken to a receptacle and elevated by creepers, two working together, so that the cotton is seized between them. By a series of creepers the cotton may then be distributed to any of the various large bins into which the floor is divided. By means of suitable mechanism the creepers can be made to deliver their burden into any part required.

When the cotton is wanted for use it is taken from the bins to another traveling creeper which conveys it to a porcupine feeder. This machine consists of a series of toothed rollers, which also have differential speeds, and the cotton is by them further opened; it then passes through fluted rollers and is beaten, the operation being performed by means of a series of disks which have projecting arms that strike against the cotton as it is held by the rollers. It is a great thing in preparing cotton in these stages to handle it lightly and not injure the fiber, while it is at the same time necessary to open out the harder masses and to remove the dirt. The operation just referred to is the first of a series of beating processes which have to be gone through, and is a very light one, the beaters not striking close to the rollers, so they do not punish the cotton much, the process forming an easy transition from the opening operation to the beating proper, which takes place later on. The system of using fans in these processes has proved a great advantage to the cotton spinner. The machines used in these stages of cotton spinning are very beautiful specimens of mechanical art, and though they run at a great number

of revolutions, there is very little vibration or jar in the best made machinery. This is necessary, as otherwise the cotton would be entirely spoilt by rough treatment.

From the last named machine the cotton is taken through a trunk by suction to the floor below into the scutching or blowing room, and is then carried in horizontal trunks of considerable length which have creepers inside. The cotton is carried forward over grids by the draught of air from the fan. Dirt or foreign matter which is mixed with it is generally of a higher specific gravity than the cotton, and this dirt falls through the grids upon which the cotton travels as it is blown along. Underneath the grids there works a continuous creeper which carries the dirt to one end of the trunk, where it falls into sacks provided for the purpose. The dirt, which consists mostly of sand and husk, having thus been removed, the cotton is taken to an opener or porcupine beater, which consists of revolving disks strung on a spindle. There are fans which draw the cotton along, and in this way it is further cleansed. The cotton next passes to the second part of this machine, which consists of a pair of cylindrical wire cages. Through the latter there is a continuous air current caused by a fan, the direction of the draught being such that the cotton is drawn on to the surface of the cages very evenly. This result is obtained automatically, as when a mass of cotton has become attached to the cage, the draught there is naturally checked somewhat, and the remainder of the cage has its normal draught. In this way a very even sheet is obtained, and at the same time a certain amount of cleansing process goes on.

On emerging from the cages of the opener the sheet of cotton is seized by fluted rollers, through which it passes, and is thus consolidated, having the appearance of a thick sheet of wadding, and is then formed into a lap, being wound into a roll on a lap rod. This roll of lap is taken to another machine, known as an intermediate lap machine, which consists of a pair of fluted rollers. Four of the laps are treated at once, this stage that a square yard of the lap should be of a given weight, otherwise the further processes will be affected throughout. It being remembered that the fleecy cotton has to be transformed into a filament, it will be seen that any inequality in the quantity of material contained in a given area of the sheet will affect the thickness of the thread, one of the great virtues of which is that it should be of uniform strength and substance. Although many equalizing processes have yet to be gone through—indeed, the whole of the operations at the initial stages consist of cleaning and equalizing—yet unless a fairly uniform web be obtained at this juncture, good results cannot be expected ultimately. It may be noticed that in all machines in this department there is a knocking off motion when a definite number of yards have been produced.

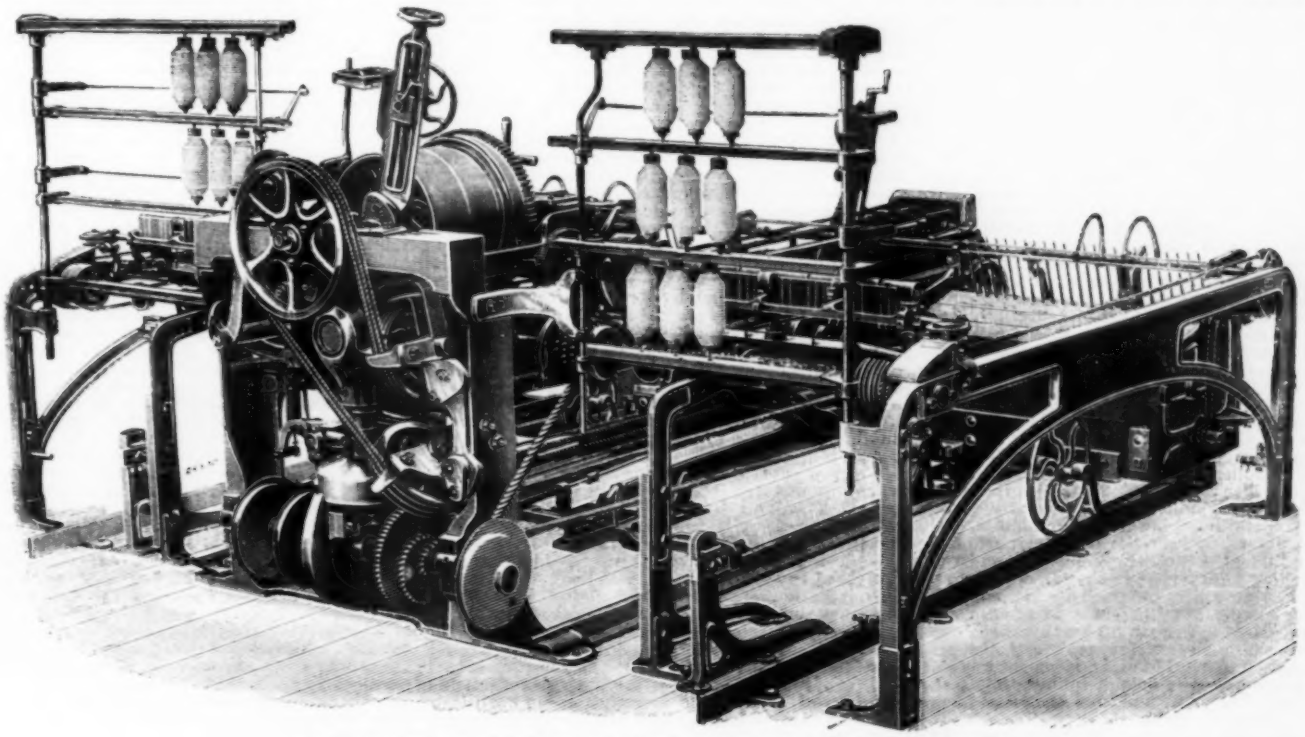
In former days, before blowing machinery had been introduced, the female operatives would take a bratful of cotton, and spread, as nearly as their skill would allow, a given weight on a given area of the creeper which took the fiber to the carding engines. It will be easily understood that, although the women were remarkably skillful in spreading the cotton evenly, the lap produced was not nearly of the equal thickness that is now obtained. A bratful of cotton was an apronful, "brat" being local vernacular for "apron." In those times the cleansing was done by hand beating with light willow rods, the cotton being placed on a net.

We now pass to another branch of the preparation of cotton for spinning. We have seen the fiber formed into large loose sheets or laps, which have been wound into rolls around rods. Great care and pains have been taken, as stated, to make these sheets of uniform thickness, but the carding engine, which comes next in order, apparently undoes the whole of the work which has been so laboriously performed. The method of operation is as follows: The lap is put on the machine, and is unrolled by means of fluted rollers. The lap is then broken up by a fine-toothed revolving

This sheet is much finer and more regular than that which was broken up by the carding engine in the first part of the operation, and though it seemed that the carding engine, as already pointed out, was undoing all the work before done, so that previous operations were useless, such indeed was not the case, for the regularity with which the cotton was delivered to the carding engine enabled the engine in turn to deliver a web of uniform texture.

The sheet as delivered by the doffer comb is taken through a pair of rolls which revolve at the somewhat higher speed than that which would deliver the cotton at the same rate at which it is fed into them, and the web is therefore a little stretched or drawn out. It then passes to rolls through a trumpet mouth, and by the latter is converted from a flat continuous film to what is really a continuous cylinder of the fleecy cotton; in fact, the trumpet mouth bends it from a flat strip to a pipe. It next passes to another pair of rolls, and from thence into the receptacle or sliver can, which is a long tin drum caused to revolve so as to give a slight twist to the cotton, which is now formed into what is known as a sliver. In the carding process separation of the shorter fiber from the long is performed; the short fiber is collected by the flats or cards, and is taken off them by what is known as the stripper comb, and is deposited in a suitable receptacle; this short fiber has a commercial value, being used for many inferior purposes. In some cases in place of flats carding engines are provided with rollers. In Messrs. Haworth's other mill, machines of the latter description may be seen at work.

The cotton as now formed into a sliver passes through a series of machines which are used for drawing out and doubling; these operations are undertaken in order to harden and equalize the sliver. In the first of the drawing machines six slivers are passed through four rollers running at different speeds, so that the material is drawn out; the combined effect is to make the material six times the length it was when it entered the first pair of rolls, and as six slivers are



BACK VIEW OF MULE HEADSTOCK WITH PART OF CARRIAGE.

RICHARD HAWORTH & CO.'S COTTON MILL.

being beaten by revolving horizontal bars in order that more dirt or foreign matter may be knocked out, the cotton being arrested by a grid through which the dirt passes. The chief object of this process, however, is to produce a more even surface. It will be seen that any inequalities there may be in the individual laps will be, by the law of averages, reduced by working four together.

By the processes we have described, not only is the dirt eliminated in a manner truly surprising to those not accustomed to the operations, but the short fiber also is removed, and in this way the cotton is prepared for spinning processes. Before, however, it is ready for spinning it is taken to another pair of cage rollers, and from thence it passes through a series of lap rollers which are smooth on their surfaces; from thence it passes through three rollers, two of which are fluted, while the third, which is smaller in diameter, is plain; these operations again form it into a lap or continuous sheet, which has sufficient cohesion to enable it to be wound on a small hollow roller. The axial hole through this roller is formed in order that that the rolled lap may be put on the lap rods without the operation of skewering being performed. When solid rollers were used, the lap rod had to be pushed through the center of the roll of cotton, and in this way the material was frequently injured. One day it occurred to some bright genius that the rollers might as well have a hole through them, and they could then be pushed out of the cotton and the lap rods be inserted at the same operation. It is satisfactory to know that the man who first throught of this made a fortune by his ingenuity.

We now pass to the finishing scutching, which is a repetition in general principle of the former process. All these processes of cleaning, regulating, breaking up, and making up again into sheets or laps, are performed in order to thoroughly mix the cotton, to cleanse and to remove the short fiber. It is very important at drum; the small pieces which are torn up are thrown on to a grid, and here any dirt that remains is removed, while the short fiber is got out. From thence the fleecy masses of cotton are taken up by the big cylinder of the machine, which is covered with short wires like the pile of coarse velvet or a long-unshaven chin. This revolves at a very high speed; while traveling in the same direction, but at a lower speed, are a number of cards or flats; these consist of what may be described as a length of coarse pile of wire, securely fastened to iron flats, as shown in both illustrations. The short wires on the cylinder clear those on the flats by a very small distance, perhaps the hundredth part of an inch. The operator regulates this distance by passing a thin steel gauge, and he can tell if properly adjusted by feel. Much practice is required to determine this point accurately. The distance between is obtained by packing up the paths at the edge of the cylinder on which the flats that carry the cards are mounted. The adjustment is done by means of very thin hardened steel bands. As the cylinder travels so much faster than the flats, the cotton is carried forward, being combed between the two series of wires, and this has the effect of placing the fibers so that they lie all in one direction, namely, circumferential to the cylinder. The necessity for this will be apparent when it is remembered that these fibers have to be spun into a thread. The cotton is taken from the cylinder by what is known as a division plate, which is set $\frac{1}{100}$ inch distance from the points of the wires of the cylinder, and the division plate puts the cotton on what is known as the doffer, which is another revolving cylinder of very much smaller diameter and covered with wires. The fiber is then taken off the doffer by the doffer comb, which is actually a steel comb, and is caused to oscillate very rapidly in front of the doffer. The fiber is thus released from the wires and is not broken, being delivered in the form of a filmy web or sheet.

combined, the thickness of the product is naturally equal to that of any one sliver. The machine delivers into a trumpet mouth, and there is a revolving can into which the resultant material is coiled, and in this way a slight twist is put in the fiber. The cans are then taken to another machine where they go through a similar process.

The material next passes to the slubbing frame, in which a single thread is passed through three pairs of rollers, by means of which it is again drawn down, but in place of being coiled in cans it is wound on bobbins by means of a spindle and flier, so that sufficient twist is put into it to enable it to be described as a fine cord, and to give it strength enough to enable it to undergo the subsequent processes. The first of these is performed in what is known as an intermediate frame, in which a process between slubbing and roving is carried out. Here two slivers are drawn together by rollers as before, and are twisted by a spindle and flier on to a bobbin, known as the intermediate bobbin. In these processes the sliver is gradually getting finer, but the twist put in it is only sufficient to give it cohesion necessary to enable it to draw the bobbins round in the next process. The roving frame performs operations which are practically a repetition of those already described; two slivers are drawn into one roving, being twisted at the same time. The cotton has now been formed into threads which are known as rovings, and it may be next made into twist or warp by means of the ring frame, or it may be spun into weft or woof* on the mule. We will take the first named operation to begin with.

The rovings, which have been wound on bobbins, are placed on the upper part of the frame. They have a certain amount of "draught" put in them by

* "Weft" is the general English term known in the trade. "Woof" is a scriptural or literary expression; while the modern American uses the word "filling" to describe the same thing.

means of the rollers running at different speeds, the twist being put in by the spindles, and they then become what is technically known as "twist." It is somewhat difficult to describe the action of this machine, as, like all textile machinery, it is complicated in its method of working. It is continuous in its action, for—as opposed to the processes of drawing out, twisting and winding on the spindle of the mule, which are intermittent—the work of the ring bobbins is carried out continuously and without intermission. The roving bobbins are mounted in the upper part of the machine, and the roving is drawn from them by rollers, and passes through a small bent piece of wire known as the traveler. This traveler is a D-shaped piece of brass wire, with a gap in the vertical part. It is placed on the ring of the machine, which is about 2 in. in diameter, and through which the spindle passes. The traveler is of varying size and weight, according to fineness of the "counts" being spun. From the traveler the thread is carried to the ring bobbin, which is mounted on the spindle. A fair sized ring frame will have 420 spindles, each with its necessary bobbins, rings, travelers, etc. The operation is as follows: As the spindle revolves it winds the thread from the roving bobbin on to the ring bobbin, through which it passes, and which it causes to rotate. It is necessary, however, to twist the roving into thread, as well as to wind it, and the necessary twist is put in by reason of the traveler putting some drag on the thread; in this way the spindle makes a greater number of revolutions than the traveler, and therefore twists the thread. In order to lay on the thread to build up the bobbin, the rail on which the rings are fixed is caused to rise and fall, so that the thread is guided to the right position.

We now pass to the mule department and give illustrations of mules made by Messrs. Platt. In the mules the roving bobbins are arranged at the back of the carriage, and the roving is drawn from these by means of rollers provided for the purpose. The carriage then comes forward, and while it does so the thread is led to the top of the revolving spindles on which it is to be wound, being guided by a long horizontal wire known as the faller wire, which rises for the purpose. During this operation twist is being put in the roving by means of the spindles, which revolve with great rapidity. The operation is exactly similar to that performed by the spinner of primitive ages, when the spindle was held suspended by its point by a thread, and was made to rotate, the spinner holding the thread in her fingers. When the motion of the carriage is reversed, so that it runs in toward the rollers, the thread is led off from the body of the spindle at right angles, or approximately right angles, and as the spindle continues to revolve, it will be seen that the thread will be wound round the spindle, and will form what is known as the "cop." It will be seen, therefore, that there are two principal operations, one consisting of twisting the thread, performed when the carriage is running out and when the faller wire leads the thread from the point of the spindle or in a line with its axis, the second operation consisting of winding the thread when the twist has been put in it on to the spindle.

There is, however, one operation which complicates the action a good deal. It is necessary to keep the thread always in tension, otherwise it would kink. The line followed by the thread when it leads from the point of the spindle to the rollers is shorter than that taken when the thread leads from the middle of the spindle to the rollers; it will be obvious, therefore, that when the faller wire attempts to guide the thread to the center of the spindle, which it does at the pause between the outward and inward stroke (that is, when the carriage is furthest from the standing part of the mule), at that time the thread would be broken by the faller wire, unless additional length of line were given. This additional length is obtained by reversing the motion of the spindle, it taking a few reverse turns, or "backing off," so as to slacken up the thread.

The mules used in Messrs Haworth's establishment are of the most advanced kind, and are entirely self-acting, an attendant only being required to join any broken thread. The mule performs the same operations as the ring frame, although, as will be seen, the result is obtained in a somewhat different manner. The mule does finer and more even work, and is, therefore, generally used for weft, the weft of the woven material being that which is generally on the surface. The ring frame is used for warp, where a stronger thread is required. Before the introduction of the ring frame, warp was spun by the throstle or flier frame, and, indeed, for many years the quicker working and more economical ring frame was strenuously opposed by English spinners, although it had obtained a firm footing in the United States. To the present day warp twist is largely spun on flier frames. As, however, Messrs. Haworth have broken all their throstles up, and replaced them by ring frames, we are not able to describe them in connection with these works. It may be stated, however, that the throstle differs from the ring frame chiefly in the fact that a flier is used in place of the traveler and ring.

We have now converted the raw cotton into warp or weft as the case may be, and it remains to weave it into textile fabric, but before this can be done certain subsidiary but important operations have to be performed.

Following up the thread which has been spun, we pass to the room which contains the winding mechanism, which transfers the thread from the ring bobbins on which it has been wound in the spinning machines to what are known as the warper's bobbins. The operation is simple, the thread being laid on evenly by a rising and falling guide plate having a slit in it through which the thread passes; the thread is also drawn at the same time through a brush; the combined effect of the brush and guide plate is to remove imperfections, for if there were any thick places in it, they would not pass through the slit in the guide plate.

The yarn is, as we have said, transferred from the ring bobbin to the winder's bobbin. It may be that six ring bobbins will be wound on to one winder's bobbin, the object being to prevent constant creeling. The warping mill, by which this operation is performed, has in it a very clever arrangement for automatically stopping the action should the warp break. A number of the winder's bobbins are next placed in the creel of the warping mill. The function of the warping mill is very simple. It transfers the yarn or twist from the bobbins or spools to the warper's beam. The threads pass through a reed or fine steel comb on their way to the beam. On each of the threads of the warp is hung a fine steel bent wire, which may be likened to a lady's hairpin. Should any thread break, the hairpin drops into the mechanism below and stops the machine by passing between two rollers and forcing them apart, thus putting into operation a gear which throws a clutch out of action. As there are often as many as 600 threads in a warp, and the breaking of one of these would be sufficient to cause the material to be rejected, it will be seen how necessary it is that automatic gears should be provided, as it could hardly be expected that an attendant would immediately detect the breaking of one thread among 600. The sudden stopping of the machine is apt to cause slackness of the thread, owing to the momentum in the bobbins, which go on unwinding after the machine has come to rest. In order to obviate this defect, tin rollers are provided, which automatically fall in the bight of the threads, and thus take up the slack. The machine has also an automatic "knock-off," which comes into play when a predetermined length of thread has been wound.

We have now the thread wound on the warper's beam, but it is not yet ready to be put into the loom, as a sizing or slashing operation has first to be performed. This is a simple process. The warper's beams are placed in the slashing sizing machine. The threads are unwound, passing through a bath of sago or other material. As many as 3,000 to 4,000 threads will be passing through the machine at one time. They then travel over the circumference of a big drying cylinder 9 ft. in diameter, and warmed by steam, and from thence they are rewound on to the weaver's beam. Fans are provided, the draught from which plays on the yarn and helps to dry it.

We must now retrace our steps somewhat to describe the process followed with dyed or bleached goods, having hitherto dealt with what are known as "gray goods," which comprise all kinds of calicoes, long cloths, twills, etc. In colored goods the first distinct operation is reeling. The twist is wound from the ring bobbin at the top of the machine round a swift, and is thus made into a hank. These hanks are made up into bundles and forwarded to the bleachers or dyers. The hanks of yarn come back from the bleachers or dyers, and are then transferred to the warper's bobbin.

The bobbins are taken to a creel, which is a large wooden frame, being arranged according to pattern in the creel, so that the threads of a required color weave to the proper part. It should be stated that in colored goods the warps are wound in sections known as "cheeses," and the name is a suggestive one, as each cheese consists of a short but very thick cylinder of thread. It is remarkable how the cheeses will stand together without the thread slipping off its turns; this result is only got by winding very closely and evenly. The number of cheeses required for any given width of cloth are threaded on to an iron shaft. The next process is to wind the thread from the cheeses to the weaver's beam. The object of winding in cheeses is that the parts should not be too unwieldy to deal with. As it is warp we are describing, it will be understood that the wider the material required, the greater number of cheeses will be required to make up the beam.

We now pass to the drawing-in or twisting room, where the weaver's beam is taken to the drawing-in frame. This is all hand work. In order to make our explanation clear, it will be necessary that we say something about the action of the ordinary loom, and though we do not suppose there are many educated people, at any rate among the industrial classes, who do not know the general principles of weaving, it is necessary that we should repeat them in order to make our description clear. The various threads which go to form the warp are wound on the weaver's beam, while the weft, which has been formed into a cop in the mule or into a pirn on the pirn winder, is contained in the shuttle. By suitable mechanism the warp is being continually unwound from the beam, and is wound on to the cloth roller, which revolves for the purpose, and round which it is wrapped after being converted into cloth. Each thread of the warp passes through what is known as a "heald." There may be two or four healds; we will deal with the simplest conditions, and suppose there are two. The heald consists of a heald shaft, which is a long lathe, to which is attached a number of threads that hang vertically in the loom. A second or lower heald shaft is attached to the bottom ends of the threads. In the middle of each thread there is worked an eye, and through each eye passes one thread of the warp. We have, therefore, a roller or weaver's beam with the warp wound round it and the end of the warp taken through the eye of the heald, and from thence to the second roller, round which it is in turn wound; the process of weaving being, therefore, a constant unwinding from one roller and winding on to the other, the cloth being formed from the threads between the two rollers.

Having proceeded so far, it may be as well to describe the operations of the drawing-in or twisting room, which are wholly hand processes. The weaver's beam is put into position, and the heald is suspended in front of it; the end of each thread in the warp is then passed through the eye in its corresponding heald, and also through the reed, which is a steel comb, the use of which will be afterward described. The whole is then taken to the loom. In the principal weaving shed in Messrs. Haworth's mills, over 800 women are at work under the charge of one man. The threads forming the warp come from the beam over what is known as the back rest, and pass two "shed rods" which, in the ordinary plain loom, divide them into two parts. These shed rods, by holding the warps apart, help the weaver to pick out a broken thread. As already stated, there are two healds placed one in front of the other; the back heald will take, say, all threads of odd numbers, supposing them to be numbered consecutively, while the front heald will take, say, all the even numbers; in this way each alternate thread will pass through an eye in one or other of the healds. The healds are given a vertical reciprocating motion by means of tabbets, and, therefore, the odd and the even numbers in the warp are made to rise one above the other alternately. The shuttle now comes into play. In it is placed the weft, as stated, and it is made to pass from side to side of the loom by means of blows from the picking stick. As the shuttle passes in one direction, say from right to left, it will travel above the warp threads of odd numbers. The heald which carries the warp threads of odd numbers will then rise, while the even-numbered warp threads will fall, and the shuttle will make its return journey, uncoiling its weft as it goes. In this way the interweaving of the warp and weft is obtained, the shuttle carrying the weft alternately first above and then below each thread of the warp. In order to press the weft closer together, what is known as the reed is provided; this may be described as a flat steel comb, each thread of the warp passing between a pair of teeth. The shuttle race is in front of the reed, and when the weft has been drawn across by the shuttle the reed comes forward, and presses it hard against the preceding weft. The division between the warps through which the shuttle goes is known as the shed. There is a stop motion provided in case the weft breaks; there is also a taking-up motion so as to regulate the closeness of the web, that is, the number of picks per inch of cloth made. As the shuttle always travels at one speed, the number of picks per minute in a given loom is constant; in some cases they go in as high as 250 per minute. The closeness of the weft is therefore obtained by altering the winding or taking-up motion. The process we have described is, of course, the most elementary form of weaving.

There are a large number of looms of all kinds in Messrs. Haworth's works, the need of them often being governed by fashion. The looms in Messrs. Haworth's weaving sheds are of all descriptions, ranging from the plain calico loom to the intricate Jacquard loom. It would be hopeless for us to attempt to describe them all. A large number have attached what is known as a "dobby," which acts by a series of levers working the healds from above. A good deal of sateen or cotton satin is made on these looms, and is now a fashionable material. There are sheeting looms which weave bed sheets up to 112 in. wide; these are plain and twill looms, remarkable only for their size.

Dobby looms are useful for changing the warp when the pattern is made by different colored threads in the warp, the weft being only one color. For forming the pattern by means of different colored weft, several shuttles have to be used, each carrying the thread of the particular color required. For instance, if a large square of blue color has to be formed, the blue shuttle will have to be brought into play for several picks continuously, and the shed will be arranged so that most threads of the warp are down, only, perhaps, one out of every three or four being up and thus passing over the weft. Looking at the cloth from above, therefore, the blue weft will be the predominant feature, while on the other side of the material the weft will be almost covered by the warp, and therefore the color of the latter will predominate. If several colors are required in a pattern, as is usually the case, the shuttles are carried in what is known as the drop box, that is to say, they are packed one above the other in a two, three, four, or five shuttle box, each shuttle resting on its own support. By suitable mechanism the box is raised or lowered so as to present the required shuttle to the blow of the picking stick, and thus send it through the shed. Sometimes the same object is obtained by circular rotating boxes. The shuttles are presented in proper order by means of a card or steel sheet which has holes pierced in it. Steel pins strike against this card, and the one which finds its hole penetrates and thus passes forward to throw a rack on to a pinion which actuates levers and so work the shuttle box to bring the right shuttle into play. Looms are made which combine the drop box and the dobby, so that the warp and weft can both be controlled, and thus produce diversified and intricate patterns.

The picking stick is actuated by a picking tabbet, or cam, which causes the stick to give a smart blow to the shuttle and thus send it through the shed of the loom to the other side, from whence it is returned by another picking stick. The beam has no motive power, but is actuated by the warp threads as they are wound onto the cloth rollers. It is necessary to keep the warp at great tension, and for this reason four weights are used, which act in a contrary direction to that in which the warp travels, thus forming a break. Complicated effects and floral patterns are produced by means of the Jacquard loom.

INSECT SECRETIONS.

By E. A. BUTLER, B.A., B.Sc.

THE fresh and luxuriant herbage, consisting of grasses and other low plants, which forms so lovely an undergrowth in woodlands and waysides in early summer, is generally seen to be more or less disfigured by the presence of numerous patches of white froth or spume scattered about over the stems and leaves. Popularly classed among that vague and indefinite group of objects known to be injurious to vegetation, to which the name of "blight" is loosely applied, these masses of froth are specifically distinguished as "cuckoo spit," "frog spittle," or "spittle blight," and so abundant and widely distributed is this substance, that it forms one of the commonest of the "common objects of the country," and there can be no one who has not been familiar with it from his earliest years. The legendary association of this froth with the cuckoo is to the effect that the bird, becoming hoarse by the constant reiteration of the same cry, is at last driven to relieve its throat in the offensive way to which the surrounding bushes bear testimony. The association with frogs, though equally wide of the mark, has a little more show of plausibility; for the froth is the produce of several curious insects which, from their strange, angular heads, and their long hind legs and great leaping powers, bear a ludicrous resemblance to minute frogs, and are commonly known as frog-hoppers. If the mass be examined, there will be found embedded within it a soft bodied greenish or yellowish creature, which is either the larva or pupa of some member of the family Cercopidæ. In the majority of cases, it would prove to be the young of one of the most abundant of all British insects, the frog-hopper par excellence, which is named scientifically Philænus spumarius.

In this insect we again have an illustration of the

order Homoptera. Like the rest of its tribe, it feeds upon the juices of plants, which it abstracts by aid of a beak-like apparatus bent under the head. The beak consists of the trough-like labium which contains pointed needles, the representatives of the jaws of the typical insect's mouth. Around the hinder part of the digestive tube, which is unusually long, lies a coiled gland, which, according to Buckton, secretes a slimy liquid; this liquid issues from the end of the body, and at the same time air is forced into it, thus throwing it up into bubbles which pass out one by one and roll round till they form a mass of froth completely enveloping the insect. It is not very easy to see how the air gains access to the liquid secretion, since the latter issues from the end of the digestive tract, which is in communication with the air at no other point than the mouth, where no air is taken in. Any air that is drawn into the body of course enters as usual at the sides through the spiracles, and passes thence into the various air tubes of the body. That the air in the bubbles does actually come from within the body, and is not drawn from the outer air at the place of their formation, seems to follow from the fact that if the insect be plunged into water, it continues for a time to emit air bubbles from the end of its body.

In order to watch the process of formation of the froth, the best plan is to adopt the method originally employed by the celebrated naturalist De Geer. He took one of the larvæ, and with a little brush carefully removed all the froth surrounding it; then he placed it on a freshly cut twig of honeysuckle, a plant much frequented by these insects. The twig was placed with its cut end in water, that the loss of moisture by evaporation might be counterbalanced, and the plant might continue to be sufficiently succulent to yield the insect an abundant supply of sap. It soon drove its beak into the stem and began to suck, continuing the operation for some time; then withdrawing its beak, it walked off to a leaf, and there began to bend the hinder part of its body about in different directions. De Geer, who was all the time watching it with a lens, soon saw a little bubble issue from the end of the digestive tract and roll round under the body. A repetition of the same movements soon produced another bubble, which followed its predecessor, and the operation was thus continued till the whole insect was covered with a pile of white bubbles, the viscidity of the liquid of which they were composed being sufficient to prevent them from bursting. Sometimes two or three specimens form their froth side by side, so that they become enveloped in a common mass.

This frothy covering serves in general a twofold purpose. In the first place the inclosed insect is protected from insectivorous foes, most of which would think twice before interfering with a sticky, slimy mass of froth, however tempting the morsel within might be. But still the immunity is not absolute; some predaceous insects are bold enough to brave the discomforts and dangers of the sticky mass and carry off its inmate. De Geer records that he saw some "small wasps" do this; these were probably not true wasps, but yellow-banded Hymenoptera, belonging to the genus Gorytes, some species of which have also been found by other observers, carrying off the larvæ to their nests. This would, however, be to serve as food for their young rather than to feast upon themselves.

The second use of the froth is that it shields the inclosed insect from the heat of the sun, which instead of drying up its delicate frame, simply promotes evaporation in the fluid mass. The loss from such evaporation is usually counterbalanced by renewed secretion, although, in very dry weather, when the vegetation is less succulent, the mass shrinks considerably in bulk, and at last reaches a degree of concentration in which evaporation seems to be almost entirely checked. In damp weather, on the other hand, the secretion is very abundant, and a clear drop of liquid devoid of bubbles often hangs at the end of the mass, ready to fall on the slightest agitation of the leaves. The soft bodied larvæ of the tribe of frog-hoppers usually feed from the under side of leaves, thus placing the broad shelter of the leaf blade between themselves and the prying eyes of birds, or the seaching rays of the sun. But the larvæ of the particular group we are now discussing, by the habit of froth secretion, are able to feed exposed on the upper surface, and still more or less successfully defy the evil influences which are the bane of their less highly protected brethren.

The insect spends the whole of its larval and pupal life enveloped in this froth, and usually feeds with its head downward; it even changes its skin while bathed in the moisture of its own distillation, and the rejected vestments may sometimes be found floating in the mass. The stickiness of the froth causes it to become a good trap for minute insects and other odds and ends that may be floating about in the air, and miscellaneous collections of such objects may sometimes be found in it. By the time the frog-hopper is ready to assume its perfect state, the froth has considerably evaporated, and then it forms a hollow envelope, not in close contact with the insect's body. Within this central cavity the final change takes place. When it has reached its ultimate form it escapes from its hollow shelter, and thenceforth dispenses altogether with the secretion, spending the rest of its days as a dry, hard bodied, vigorously leaping creature, which, though common enough, and frequently seen, is so changed in appearance that it is not likely to be associated, in the minds of those ignorant of its history, with the frothy masses which disfigured the plants a few weeks earlier.

Philænus spumarius is one of the most variable insects of which our country can boast, and any attempt to describe its coloration briefly is almost futile, for it is not easy to find two specimens alike. Its angular head, its stout and spiny hind legs, and its horny upper wings, slightly rounded on the outer edge, will at once enable it to be recognized quite apart from coloration. It is sometimes brownish, more or less speckled and spotted with paler markings; or, again, it has black upper wings and a whitish head, or purplish black upper wings with conspicuous white bands upon them. Sometimes it is entirely pale drab, or yellowish brown, with a pinkish tinge. And so one might go on describing variety after variety of the most opposite appearances, yet all agreeing in shape and structure, and evidently no more than mere varieties of the same insect. Upward of a dozen of these varieties are sufficiently constant to have received distinctive names.

Considering its extraordinary abundance, Philænus spumarius probably does far less damage than might have been anticipated, though, of course, the abstraction of sap from the young and growing parts of plants has always the effect of stunting their growth and producing malformations. But in gardens there is more reason to dislike it because of the disagreeable appearance of spittle-like masses clinging to the plants, and the ease with which they become transferred to one's fingers, than for the actual amount of damage done. The insect, though a very general feeder, is somewhat of an epicure in its tastes, and requires its food in a very fresh state. Hence it is not easy to keep in confinement except on growing plants, for if the sap at all deteriorates in quality, the creature crawls out of its froth and goes in search of more favorable quarters; not being able to find such, it resigns itself to death rather than touch food of an inferior quality. Its habit of living enveloped in moisture enables it to endure immersion in water for a considerable time. When first put in it emits bubbles, as already described, till its supply of air is exhausted, and then lies quiescent and apparently dead. But on being taken out, even after an hour's submergence, it recovers and seems none the worse for its experience.

We have already pointed out that the froth of the Cercopidæ is not wholly effective in preserving the larvæ from the attacks of other insects, and this is true also when those insects are parasites on the lookout for a suitable place of deposit for their eggs. Small ichneumon flies manage to gain access to the larvæ of the different species of spittle blight and lay their eggs in their bodies. In such cases, Mr. Buckton speaks of having found the shriveled body of the host, after the maturation and exclusion of the parasite, enveloped in a kind of cage of hollow network, consisting of the dried up remains of the frothy cover. This was a larger species than that described above, and belonged to the genus Aphrophora (foam bearer), a name originally assigned to all these insects because of their frothy secretion. The species in question is found chiefly on willows, and is not nearly so common as Philænus spumarius. We have altogether seven species of frog-hoppers in this country that manifest the habit of froth-forming, one of which, the scarlet-hopper, is an extremely handsome insect with black wings crossed with blood-red bands.

The honey dew of aphides is another homopterous product of considerable interest. The majority of the aphides carry on the sixth segment of the body a pair of tubes pointing more or less upward and outward, and called "cornicles." Out of these tubes there may at times be seen to issue drops of a saccharine liquid, which remain for a while adherent to the end of the tube and then drop off. This is what is known as honey dew, so called from its being found sprinkled as sweet and sticky patches on the surface of leaves, as if the air had deposited honey in the same way as dew. Such, indeed, was the origin assigned to it in ancient times, as it appeared on the leaves of trees without any obvious cause, and Pliny in referring to it shows that he was divided in his mind as to whether he should ascribe to it a celestial or a mundane origin—whether, in fact, he should regard it as the "sweat of the heavens, the saliva of the stars, or a liquid produced by the purgation of the air."

The cornicles of aphides do not appear to be directly connected with secreting glands, but simply to open into, or rather from, the cavity of the body. The saccharine liquid is ejected not merely from these cornicles, but also from the extremity of the digestive tract, whence it is sometimes forcibly shot to some considerable distance. Buckton states, with reference to the black aphis which is found on willows, that if its abdomen be stimulated with a bristle, it will erect the terminal rings of its body, and upon the apex there will appear a clear drop of liquid. If ants happen to be near at the time, they will at once abstract this, but if not, the aphis projects the globule with a jerk to a considerable distance, and in consequence it falls on the leaves below.

The leaves of some trees are often seen to be thickly covered with spots of this sticky substance. The lime tree is specially noted in this connection, and when such a tree grows in a garden and overhangs the pavement, it is matter of common observation that the surface of the latter underneath the tree becomes, during the course of the summer, thickly bespattered with drops of the same honey, as though there had been a constant rain of it on to the ground. In such cases the question has arisen, and it is one that has provoked a good deal of controversy, whether the fluid is not a direct product of the tree itself rather than of the aphides, and such an idea seems to gain support from the fact that the trees that give the most plentiful showers on the ground and have their leaves in the most foul condition are not always those that are most infested with aphides. There seems to be some probability that both statements are true. It is certain that aphides do produce such a liquid as this, and indeed its manufacture by them forms the reason why ants keep stores of aphides for their own profit. If the liquid does not exude from the bodies of the aphides naturally, when required by the ants, they will stimulate the creatures to yield it, by stroking their bodies with their antennæ. Under this gentle stimulus, drops of liquid soon issue from the cornicles and are eagerly received by the attendant ants. It seems likely that just as the milking of a cow by a human being is a relief to the animal through the relaxation given to the painfully distended udder, so the aphis may feel it a relief to discharge, under the stimulus of the ant's antennæ, the fluid with which its body is fully charged, and thus the operation may be an advantage to both parties to the compact. Harting collected some honey dew from the aphides of the lime tree, which were caused to discharge it on a glass plate; it was analyzed and found to consist chiefly of cane sugar.

But the fact that aphides do secrete honey dew, deriving it ultimately, of course, from the sap of trees, is no reason why a similar product may not also be elaborated by the plants themselves; and it is certainly difficult to believe that the great amount that is found on the leaves of limes, maples, etc., as well as on the ground beneath them, has its origin entirely with the insects. A similar liquid occurs, in the form of globules, in the pseudo galls produced on poplar and other trees by the agency of aphides. Passerini says that in Italy this substance is collected from the leaves of elm trees, and used by the villagers, under the name of St. John's oil, for the dressing of wounds. In the same way the liquid found in the aphideous galls of the elms is said to be used in France, under the name of elm water, as a remedy for sore eyes.

Aphides are not the only insects that secrete a substance grateful to ants. Several other insects belonging to the order Homoptera, and especially to the section of frog-hoppers, are attended and caressed by ants, who evidently derive something agreeable from them. The following details, which have been communicated to me by a correspondent, refer to a kind of frog-hopper which is an inhabitant of Australia, in the neighborhood of Sydney.

"We first noticed the ants running about on the twigs of a bush in an apparently excited but inconsequent manner, and on looking closer we found they were swarming over a number of the frog-hoppers distributed over the branches as if they were aware of the presence of something which they failed exactly to localize. Watching isolated couples, we noticed every now and then a small drop of clear substance resembling honey exude from the frog-hopper rather more than three parts down its back, which the ant immediately slipped round and devoured. There did not seem to be a systematic milking, as in the case of the plant lice, but the ants, in trying to find the secretion, seemed to hit upon the trick accidentally. The insects did not make the slightest effort to get away; they all seemed in a drowsy condition, and in many instances crowds of ants were swarming over them." Some American ants have also been observed licking the caterpillars of a certain blue butterfly, over which they assume guardianship. The caterpillar secretes from an oval gland on its back a sweet liquid which is much sought after by the ants, who stimulate its flow with their antennæ and then eagerly lick it up. In some places they are even said to go so far as to treat the caterpillars in much the same way as certain British species do their aphides, by erecting a sort of earthen shed over them to protect them when they become pupæ.

It is probable that a good many caterpillars have the power of secreting liquids of one kind or other, which are no doubt useful for protective purposes. The caterpillar of the puss moth is remarkable in this way, as it has the power of discharging formic acid from a gland situated beneath the mouth, a portion of the gland itself being at the same time everted. Similarly the caterpillar of the beautiful swallow-tail butterfly, when alarmed, thrusts out a forked appendage behind its head and exhales a strong odor of fennel. The stinging glandular hairs of the processionary moths, as well as of our English gold tails and brown tails, are other instances of protective secretions. The caterpillar of the goat moth, again, receives its popular name from the secretion, which gives it so strong a smell that its burrows in the solid wood of tree trunks become deeply impregnated, and its presence can be recognized at a distance by the powerful odor emanating from them. Some caterpillars when handled cause a disagreeable dark green or brown liquid to issue from their mouths, and thus no doubt often escape from their enemies.

The habit of secreting liquids is carried to an excess by the larvæ of certain saw flies. They are pale, greenish, fleshy, caterpillar-like beings, covered with little warts. They are found on hawthorn and other bushes, on the leaves of which they may be noticed lying with their tail coiled round toward the head, and making no attempt at concealment. Their bodies are generally rather stiff, and the skin seems fully distended; just above the spiracles are minute openings from which a clear acid liquid can be forcibly squirted to some distance, and when the creature is seized with the fingers, one is sure to receive a little battery of jets before it resigns itself to its fate. Another and much smaller species covers its body with a horrible slime, which gives it a slug-like appearance, whence its popular name of slug worm. Not only do these slug worms look repulsive, but they also exhale a sickening smell, which is particularly noticeable when a number are feeding together. They do great damage to fruit trees, eating away most of the soft part of the leaves.—Knowledge.

[FROM THE NEW YORK OBSERVER.]

SOME AFRICAN PESTS.

By MARY FERGUSON.

IN the journal of a lady who a number of years ago went to Africa to engage in missionary work, we may find several vivid descriptions of some of the various smaller animals which, possibly feeling their especial realms invaded, prove annoying to mankind. The "drivers," a species of ant, so called, presumably, because people flee before them, are among the most prominent of these "pests."

Miss Brittan became acquainted with them very soon after her arrival in Africa. She was walking in the garden one day when she felt a sudden and remarkably keen and biting pain. She ran hastily into the house to search for the cause and discovered four insects which she was told were "drivers." From the extreme discomfort and suffering she experienced in those few moments she was enabled to believe in the truth of stories she had heard concerning the possibilities which an army of them possessed.

The ants were about one-half an inch long, of a shining dark brown color, and had foreclaws much resembling those of a lobster; these foreclaws were a part of their accouterments of war.

The "drivers" are much feared by the inhabitants, who hurriedly leave their houses on the approach of a visiting host of them. The dread of the people, however, is for themselves, not for their belongings, for the ants so thoroughly clear their premises from every living thing that the natives are not unwilling to have their houses thus occasionally visited. Insects of every kind, rats, mice, and small vermin disappear magically before their voracity.

The "drivers" have indeed a most insatiable appetite for animal food. Dead animals afford dainty feasts to their unfastidious tastes, and they attack

living animals of all kinds—even the largest when they are at all disabled—eating the fleshy portions entirely, leaving nothing but the well cleaned and shining bones. Even men are not safe from their attacks, and must fly at their approach if they do not wish to be sacrificed. A sick man who was left alone in his house for a few hours was found by the returning members of the family to have become a victim to these marauders, and nought was left except his skeleton.

The natives, it is said, sometimes take a person who has committed an offense, bind him to helplessness, and lay him in the pathway of the ants. His death is certain, and, though speedy, it must be an extremely torturing and terrible one.

The "drivers" march along in regular files, soldier fashion, eight or ten abreast. About every sixth row another ant, larger, and jet black in color, marches either beside them or between the ranks, like a captain. They certainly seem to act the part of leaders, and to rank above the "rank and file" of the soldiery. They never march with the latter, nor do they march together; each goes singly, each attends to his own corps, except at times when they meet for consultation. A necessity for consultation arises when anything obstructs the course of the army; then all halt, and the captains congregate, apparently consider the situation, sometimes sending out deputations to explore, and finally deciding upon the best course to pursue, when the army is again set in motion, for they proceed at once to act upon the decision.

Sometimes it is necessary for the host to cross a little rivulet that is too deep for them to wade. This causes a halt, and the manner in which the difficulty is met and surmounted indicates not only qualities of thought and constructiveness, but also a generous willingness on the part of a few to sacrifice themselves for the benefit of the many. When such a crossing is to be made the captains consult, then "three or four of them place themselves side by side, standing upright on their hind feet, others climb upon their shoulders and lock their forefeet in the forefeet of the first, with their heads placed upon their heads. A second set climb on these, locking themselves with the previous ones, these throw their bodies out horizontally, their middle claws entwining around each other; others again join to them until the obstacle is spanned.' Thus a natural bridge is built, over which the army passes. The bridge then breaks up, but in this breaking up some of those composing it always perish. One can but believe that those who offer themselves know the risks to which they expose themselves, and take them willingly as well as wittingly.

Persons can stand aside and watch the movements and maneuvers of these hosts for hours without incurring any danger, if they are but careful not to get in the line of march, nor in any way to disturb or molest them.

Flies were not numerous in the part of Africa to which our missionaries went; nor were mosquitoes plentiful. But there were plenty of the creatures which are common in hot climates. The "tick" was one of these. This little insect, which is known also in our own country, has a habit of burying itself in the flesh of the feet and legs of a human being, a process which causes a peculiar sharp and burning pain and which develops, later, little festers that are quite painful for a number of days.

Centipedes and scorpions are numerous, little red ants exist in myriads, infesting everything, and there are troublesome winged ants which fly about at night; there are multitudes of spiders—some of immense size, occasionally having bodies as large as a twenty-five cent piece; lizards too, grow very large, and play about everywhere, and they are sometimes very beautiful, their colors being so bright and vivid.

As these creatures invade the houses at will, the inhabitants have to be on the alert if they wish to be secure from their presence. People there never think of dressing without carefully shaking out each article before putting it on, in order to feel as certain as may be that neither centipede, scorpion nor spider is lurking within the folds of their apparel.

A species of small scorpion has a bite scarcely more poisonous than the sting of a wasp, but the larger varieties possess more virulently poisonous properties. The bite of the centipede is sometimes, but not generally, fatal, yet it is very poisonous and causes its victims severe suffering. Rats are very numerous and very bold; they attack even living human beings if they are unable, through illness or other causes, to resist them; and bats fly about the rooms of the dwellings, after the lamps are lighted, with the utmost familiarity and freedom.

There, as in other climes, snakes of many kinds are ever presenting themselves. Miss Brittan told of the attendance of a snake at the church services. It was accidental, we may suppose, at first, compulsory afterward. It crawled into the church and some of those who were present endeavored to drive it out. It did not incline to depart, however, and wriggled itself partially into a hole, leaving two feet of tail protruding. One of the men seized this and bound it fast to the chancel, so that his snakeship should at least be unable to wriggle himself out again and perambulate the building. After the services were over the reptile was slaughtered and was found to be a young boa constrictor, seven and one-half feet in length. If it had been able to free itself it is safe to conclude that it would have created a sensation, even in an audience to whom such creatures are not strangers.

DYNAMITE IN ANTIQUITY.

THE title of this article will not fail to cause our readers a certain amount of surprise, but we could not find a better one for proposing a question of history to those of them who practice chemistry.

It has been jokingly and many times said that Hannibal, in order to get the better of the obstacle of the Alps, employed in succession, to use a chemical expression, the wet and the dry way, that he burned, reduced to ashes and finally treated by vinegar the rocks that opposed his passage.

It is well to go back to the source of this singular legend, and, to this effect, to solicit the texts.

Now, it is unquestionable that Juvenal and Servius attribute the success of the operation of the Carthaginian engineers solely to the use of a substance that they designate as acetum. Ammianus Marcellinus causes not only acetum but also an intense flame to act. Titus Livius and Appianus admit the successive and concurrent action of a flame, iron tools and acetum or ὄξος.

Before probing the sense of this term, which, at first sight, seems strange, it is well to mention certain processes of exploiting mines and quarries, as well as an original method of making breaches in walls used in antiquity.

The ancient quarrymen and miners were accustomed to have recourse to the action of flames for mellowing hard ground and disintegrating rocks and rendering them friable. This fact, narrated by Diodorus Siculus, is clearly confirmed by Pliny, who adds: "When the action of fire is found to be inadequate, recourse is had to the use of acetum, the effects of which are irresistible."

What Pliny says, moreover, is far from being an isolated assertion. Dion Cassius informs us that Metellus, while besieging the city of Eleutheræ, in Crete, kept up an intercourse with persons in the place, and that his secret agents were enabled to effect therein the crumbling and destruction of a tower by treating the masonry of the wall with ὄξος.

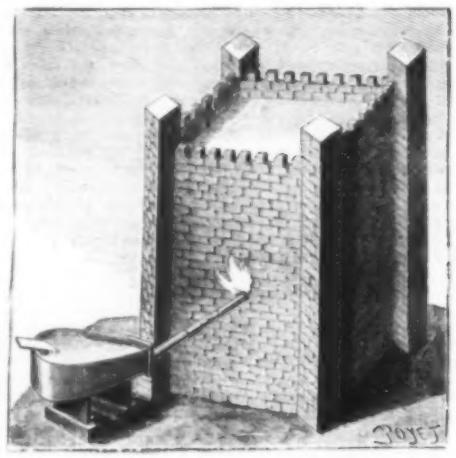


FIG. 1.—ARRANGEMENT OF A FURNACE FOR MAKING A BREACH IN MASONRY.

(From a Byzantine MS. of the Poliorcetica of Appolodorus.)

If the criticism of this historian seems tarnished, as is often the case with that of Pliny, with levity and love of the marvelous, we may consult the didactic treatises left us by Græco-Roman antiquity, and for example turn over the leaves of the Poliorcetica of Apollodorus, a contemporary of the Emperor Hadrian. This engineer teaches an infallible method of making breaches in the escarpment walls of a fortified town. In order to reach this result, says he, it suffices to direct the flames of a furnace against the stones, and a breakage will occur as soon as the action of ὄξος is made to intervene in the phenomenon of combustion (Fig. 1). It is, therefore, very certain that, at least as long ago as the beginning of the Christian era, this ὄξος was in current and, so to speak, classic use, when it was a question of destroying a panel of a masonry wall.

The use of this method seems to have been invariably perpetuated up to the time of the invention of gunpowder, since the compiler known by the name of Anonymus or Heron of Byzantium, and who very probably lived in the tenth century of our era, reproduces Apollodorus' text almost literally, and, like him, indicates the arrangement of the breaking furnace (Fig. 2).

Upon the whole, what is important to remember is that the ancients, when they were obliged to open breaches or attack a solid rock, were accustomed to have recourse to the use of an agent called ὄξος or acetum, which singularly facilitated the work of destruction and rendered the execution of it rapid.

What was the formula of this agent? That is for chemistry to pronounce, if it is possible.

Let us observe upon this subject that the ancients knew several other substances that possessed the energetic properties of the ὄξος, and that were classed by them in the group of their dynamites τῶν δριμέων. Heron of Byzantium arranges οὖρον among the number of these breaking materials and makes it the equivalent of the ὄξος.

These materials, according to their preparation, possessed well defined degrees of force. In this regard, Marcus Græcus, author of the Liber ignium ad comburendos hostes, clearly distinguishes the ordinary acetum from the acetum acutum sive forte; and the recent οὖρον from the urina antiqua. Aside from its destructive power, the ὄξος or acetum was endowed with another property, which is duly pointed out by Marcus Græcus and Albert d'Aix—that of extinguishing the Greek fire.

Such are the data that may serve for solving the problem. In awaiting a solution, and whatever be our incompetency, we do not fear to formulate a hypothesis.

It is permissible to think that the ὄξος was a highly oxygenated substance. If we observe, on another hand, that Heron of Byzantium likens the effects of it to those of the οὖρον, and that Marcus Græcus makes, in certain respects, the acetum acutum an equivalent of the urina antiqua, we shall judge that the product in question was likewise rich in nitrogen, and that consequently we find ourselves in the presence, perhaps, of a chlorate or a nitrate of potassa.

At all events, it is very certain that the ὄξος or acetum was not an acetic acid or a vinegar, as a certain number of commentators would have it, but another substance, whose formula has not descended to us. This energetic agent, used by the ancients in the course of their operations of demolition and blowing up, behaved after the manner of our modern explosives.

Once again, it belongs to chemists to elucidate the question, to make known to us what the dynamites of antiquity could have been, and to tell us what likelihood there is at the bottom of that Hindoo legend Ὀχύδρακαι of which Strabo speaks, and which, says Rabelais, "a force de fouldres, tonnoires, gresles, esclaires, tempestes, vaincquoyent et a mort soubdaine mettoyent leurs enemys en plein champ de bataille."—LT.-COL. HENNEBERT, in La Nature.

PREHISTORIC REMAINS IN FLORIDA.

ASIDE from the now world-famed attractions of its scenery and its climate, the east coast of Florida possesses much of interest to the naturalist and the archæologist. There are many evidences that a portion of this coast was quite thickly settled in prehistoric times, and remains of this settlement are found in refuse heaps of villages and single habitations. These heaps are from a few square yards to many acres in extent, and from one to fifteen feet in depth. They must have been the abode of a race for many generations. In a paper on these shell heaps, which now forms a part of the "Proceedings of the United States National Museum," Dr. DeWitt Webb, of St. Augustine, says:

"These remains indicate that the variety of food obtained was great, and include all kinds of shell fish, from the large Busycon pervensum to the tiny Donax, numerous kinds of fish, and a species of turtle, together with various birds and mammals which now inhabit the peninsula.

EVIDENCES OF CANNIBALISM.

"The skull of a whale has also been found. In connection with these remains are found the various members of the human skeleton in positions which would at least suggest cannibalism. There are hearths with accumulations of ashes and shells mingled with pottery (mostly in fragments), and implements and weapons of shell. These implements and weapons tell us all we know of the mode of life of the race which inhabited the region, and enable us more or less correctly to reconstruct this early society. That the people were hunters and fishers, the variety of animals, birds, and fish which went to supply their larder abundantly testifies. The porpoise seems to have been a favorite article of food, while the remains of the manatee are found in the shell heaps farther north than the present habit of the animal. The whale whose remains were found beneath one of the large heaps, at least a quarter of a mile from the ocean, may have been stranded on the beach, but all the other fish, birds and animals were doubtless captured by the wary and active savage. It would seem, too, as if many of the fish might have been taken with some kind of a net, as they must have employed a twisted cord for many purposes. There are marks on much of the pottery, showing it to have been moulded in baskets made of cord. Sinkers of various shapes were used.

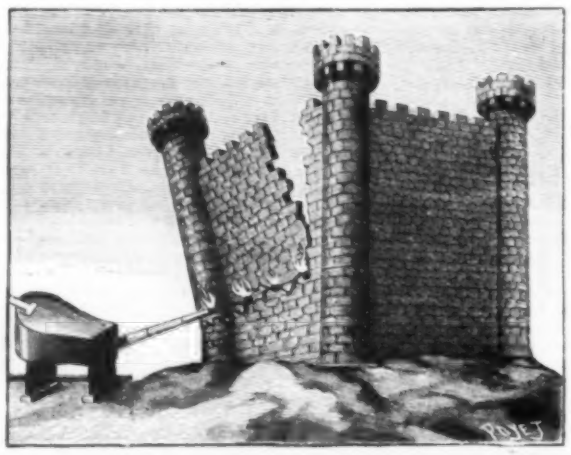


FIG. 2.—DESTRUCTION OF MASONRY THROUGH ΟΞΟΣ DYNAMITE.

(From a Byzantine MS. of the Poliorcetica of Appolodorus.)

IMPLEMENTS OF SHELL.

"The implements of shell were, for the most part, constructed from the Busycon carica, and the St. Augustine collection shows all forms and stages of this construction. While the use to which the greater number of the implements of shell must have been put is obvious, there is much uncertainty regarding others, which are found in abundance. One of these, known as the perforated shell, may have been used for the dressing of skins, and the perforation, which has provoked so much speculation, made for the insertion of the finger to give more firmness to the grasp.

"Another, found in abundance, is made usually from the smaller shells of the Strombus, and is worked as near as possible to the form of a ball. They may have been playthings of the children. The drinking shells were prepared with great care, and seem also to have been used as cooking utensils, some of them showing marks of exposure to fire. From the great number of perforated shells found on one small heap, I was led to conclude that it was in some sense a manufactory of these articles. Some of these scrapers or gouges show as sharp an edge as it is possible for a shell to receive, while others are dull. Other utensils take the form of spoons. A granite or other pebble with an end flattened and polished was probably used to put an edge on such implements as required to be sharpened.

"The pottery, though mostly in fragments, affords an interesting study, and shows great variety of design in its ornamentation. Some of the vessels were made in baskets woven from cord, while others, from the peculiar marking on their external surface, must have been made in another way. The great smoothness and perfect regularity of these vessels are remarkable. They vary much as to the character of the material of which they are made. Some are of pure clay; and of these some are thoroughly baked and hardened, while others are slightly baked, and, therefore, brittle. Others have an admixture, to a greater or less degree, of sand, and are harder. In size they vary from a bowl holding one or two quarts to vessels holding five gallons, and in shape from a shallow pan-like dish to a pot or vessel resembling a jug. The ornamentation includes about one hundred different designs. It is easy to understand the origin of the fine, cord-like markings which appear on the surface of those vessels which were moulded in baskets.

POTTERY VESSELS.

"Other vessels were apparently ornamented by using a pen-like instrument made from a reed, while the clay was soft, and still others by rolling portions of the soft clay and then putting them on as a housewife sometimes ornaments her pie crusts. In one specimen, the impress of the fingers is plainly visible, showing even the texture of the skin. By far the larger portion, however, appears to have been ornamented by the use of a stamp, which left the surface arranged in squares, as shown in the plate. Fully three-fourths of the pottery found is ornamented in this way. These vessels must have served for cooking as well as for holding water, as many are blackened from exposure to the fire. While it is probable that these people cooked the greater part of their food by roasting over the fire, yet the tiny Donax shells at least, which are present in immense numbers, must have been boiled in water to obtain a broth. They are too small to have been cooked in any other way. The number and extent of the hearths and the amount of ashes proves that the Indigenes usually cooked their food.

"The form of the mounds and collections of shells is of interest, and some of the larger ones may enable us to determine the prehistoric habitation. When individual families dwelt by themselves, there would be one slowly growing heap for each, which after a time might be abandoned. When a comparatively wide extent was occupied, the remains would take the form of what we now call shell fields—places where the ground for many acres appears to be full of shells, but without elevations rising above the general level. A form common among the heaps is that of a long bank or mound, from two to ten or more feet in thickness, and covering from one to several acres, always near the water and usually in proximity to an inlet of the sea. Scattered through these heaps, from the surface of the soil beneath their summits, are found implements, utensils, and fragments of pottery. A hearth, with a foot or more of ashes and six feet or even more across, may be found, with five or six feet of shells above it. This disposition of remains gives a clew to the manner of formation of the mounds, and is well shown in the large mound below Matanzas Inlet, which covers more than thirty acres."

VISITING THE MOUNDS.

Out of an interest and a curiosity aroused by the reading of Dr. Webb's paper, the Citizen correspondent paid a visit to this mound. The side facing the Atlantic was found to be from ten to twelve feet in depth, as Dr. Webb has described it, but it has suffered from the encroachment of the sea to an extent which cannot be determined. "The highest part of this mound," continues Dr. Webb in his description, "covers about two acres, and back of this, extending to the Matanzas River, lies the remainder, disposed in circles of greater or less extent, and covered with forest. These circles adjoin each other over a large part of the territory. They are from four to eight feet in depth and from twelve to fifteen feet across at the bottom. This was a dwelling place, and the daily refuse was thrown out on all sides, and so the circles of shells, bones, etc., gradually grew higher and higher, surrounding the rude dwelling like a wall. This wall would also serve for protection from the winds of winter, and likewise as a pit for defense in case of attack. When this hollow had become too deep, or the wall about it too high, it would be abandoned, and the owner, pitching his tent on the top of surrounding ridges, would use the hollow as a pit in which to throw refuse.

"The mound of which I am now speaking would appear to have been in some sort a center of population for many miles around. A spring of water lies in the midst of it, and the waterway was kept open to the river. Smaller mounds are found scattered up and down the river for several miles in the vicinity. One of these, some two miles north and near the inlet at Matanzas Bar, was perhaps used as a lookout and signal station. A large part of this mound was removed from the northeast part, and was piled up on the remainder, forming a peak about thirty-five feet high. From this point a good view is obtained for several miles along the level country, and an approaching enemy could easily be seen. A covered way or ditch runs from the base to the summit, thus hiding those who were passing from the sight of the enemy.

"As to the age of these heaps, all must be left to conjecture. Trees hundreds of years old are scattered over them. All instruments and implements of wood have long since perished, and not even a tradition of them remains. These shell heaps appear to be older than the earth mounds which sometimes adjoin them."

RUBUS JAPONICUS TRICOLOR.

THE cut specimens of this extremely beautiful form of the Japanese bramble, exhibited by Messrs. J. Veitch & Sons at the meeting of the Royal Horticultural Society on July 10, received much attention, and it is not surprising this should have been the case, for no more attractive hardy plant, with variegated leafage, has been introduced to public notice of late years. Like the species, this variety is vigorous in growth, has an elegant habit and is well suited for planting in position where it can be allowed to extend freely. The leaves are comparatively small, some being green variegated with white, others are green marked with white and rose, and many are white tinted with rose. The stems are also brightly colored and greatly enhance the attractiveness of the sprays, which, it may be added, are of much value for indoor decorations. A certificate of the first class was conferred upon the plant by the floral committee of R.H.S. on the date given above.—The Gardeners' Magazine.

RUBUS JAPONICUS TRICOLOR.

THE ORIGIN OF THE GOLD OF QUARTZ VEINS.

By Prof. J. LOGAN LOBLEY, F.G.S., etc.

NOT more than thirty years ago the hypothesis of the igneous origin of the "vein stuff" of mineral veins was stoutly advocated by eminent geologists, and yet to-day the theory, so far as regards the earthy minerals of a vein, may almost be considered to be obsolete. The gold of quartz veins, however, is still held by many to have been introduced into the interstices of the quartz by igneous action. There are others, again, who, while admitting the aqueous introduction of the gold into the veins, still maintain the theory of its earlier igneous uprise from the deep interior into the massive rocks containing the veins. Recent observations and discoveries by geologists and chemists have now, however, laid the foundations for a theory which attributes the gold of quartz veins not only to an aqueous conveyance to the veins, but to an aqueous origin also, since it makes the waters of the sea the source of the gold.

The opinion of Sir Roderick Murchison, that auriferous veins were confined to Palæozoic rocks or the neighborhood of igneous eruptions, has been contradicted by the finding of gold-bearing quartz veins in California traversing Cretaceous and Tertiary strata, even in localities where there are no indications of igneous action having taken place either in Cretaceous or Tertiary times. This goes far to displace the igneous hypothesis; but there is a fact of very great significance in this controversy which seems to have been strangely overlooked by the disputants. It is the remarkable absence of gold from volcanic products.

If gold was originally derived from plutonic sources, it ought to be found among volcanic products which come from the same deep-seated sources, and only differ from plutonic rocks in having been soldified under different conditions. But, although a most widely distributed metal, gold is almost if not quite unknown as a volcanic product. That quartz veins and metalliferous lodes containing the precious metal occur in some regions that have been subjected to volcanic action is true, but other regions of a still more pronounced volcanic character are non-auriferous. It is, too, a most important consideration that in gold-producing volcanic regions, the gold is rather in the veins traversing the non-volcanic rocks than in the volcanic rocks themselves. It may also be asked, Why is not gold a usual product of volcanic regions? So far, indeed, from volcanic districts being usually auriferous, the reverse is the case, for the usual non-association of gold with volcanic products is a conspicuous fact, and a much more remarkable and telling one than its mere statement suggests, both from the very wide distribution of gold and the richness of volcanic products in mineral species, metallic as well as non-metallic.

In the British Islands, gold was found in the non-volcanic districts of Sutherlandshire and the Lead Hills in Scotland, but not in the volcanic districts of Edinburgh, Skye, Mull, or Arran. In Wales, gold occurs at Barmouth and near Llandovery, but not at Cader Idris, Snowdon, or the Breidden Hills, where are volcanic rocks; and in England, gold has never been reported from the Clee Hills or the Wrekin, both volcanic, but from the valleys of Somersetshire and Devonshire. In Ireland, again, the gold districts of Wicklow, Londonderry, and Limerick are non-volcanic, while in volcanic Antrim and Kerry auriferous deposits are unknown.

But, to go further afield, the great volcanic island of Iceland is devoid of gold, as are also the eminently volcanic areas of Sicily, the Lipari and the Pouza Islands, as well as the several extinct volcanic districts of Italy. The great volcanic district of Auvergne in Central France, and the volcanic districts of the Eifel and the Siebengeberge, in Germany, are all non-auriferous; but we seek for gold with success in the bed of the Rhine that brings detritus from the non-volcanic Alps, and find it in situ in the non-volcanic

rocks of Schemnitz, in Hungary, and the Abrudbanya, in Transylvania, while the volcanic trachytes of these districts are devoid of the precious metal.

Nor is the absence of gold from volcanic products only noticeable in the European part of the earth's surface. Quite on the other side of the globe, in the volcanic islands of the Pacific, gold is also conspicuous by its absence, but non-volcanic New South Wales and Queensland are richly auriferous; and although there is gold in the volcanic North Island of New Zealand, there is very much more in the non-volcanic South Island, while that in the North Island is not in volcanic rocks. The gold fields of India are not among the volcanic rocks of the Deccan, but on the non-volcanic plains of Mysore, and the great auriferous regions of Northern Asia are in the Urals, and the central and eastern parts of Siberia, all non-volcanic. Western Africa, too, distant from the volcanic Cameroons, gives to the Gold Coast its auriferous sands, but from the altogether volcanic Canary Islands gold is not obtained.

But certainly the most striking example of the non-auriferous character of volcanic products has yet to be mentioned. The Vesuvian area of about one hundred square miles has produced by far the greatest variety of minerals of any area of even a hundred times its extent, no less than one hundred and twelve species being given in the descriptive catalogue in my "Mount Vesuvius" of 1898. These include a number of metallic minerals, but neither gold nor any salt of gold, or auriferous compound or alloy of any kind, has ever been noted, notwithstanding the diligent examination to which Vesuvian products have been subjected by competent observers for a long period of time.

The occurrence of rich auriferous detritus beneath masses of lava, both in California and in Victoria, has no bearing on the question, since these detrital deposits are not derived from the place where they now are, but from hills at a considerable distance, in which were the auriferous veins long before the outburst of the lavas now covering the beds that have resulted from the erosion of the rocks of which those elevations were formed. Indeed, in view of the wide dissemination of gold in the rocks of every continent, and its absence from so many widely separated volcanic regions, it would seem to be but a fair and reasonable conclusion that the gold of the surface rocks has not been derived from volcanic sources, and, therefore, not from the sources of plutonic rocks, and consequently not by igneous action.

The aqueous hypothesis of the occurrence of metallic gold in quartz veins is based on the following considerations: Gold is one of the most insoluble and unchanging of minerals, whether metallic or non-metallic. It is not oxidized by either air or water, and is not attacked by any of the ordinary acids, much less is it dissolved by water, either hot or cold. But it chemically unites with some, though very few, elements, and so forms auric compounds, and these compounds are soluble to a greater or less extent in water, and it is itself soluble in selenic acid and also in aqua-regia or nitro-hydrochloric acid under certain conditions. Chlorine is one of the few elements with which gold forms a chemical compound, and this salt of gold, the auric chloride, or the terchloride of gold, is readily dissolved by water at ordinary temperatures. With sulphur a sulphide of gold is formed that is also a soluble salt, though not nearly so much so as is the chloride.

The long-continued unsuccessful efforts to crystallize carbon and alumina, though minute diamonds and rubies were eventually produced, sufficiently show that in Nature's laboratory conditions obtain that can only with the greatest difficulty be produced artificially. It seems probable that under natural conditions of heat and pressure gold will unite with silica, forming a silicate of gold slightly soluble in hot water. Thus the same conditions that favor the solution of silica itself, which, as is well known, is slightly soluble in hot water, and the deposition of it in cavities or fissures, would likewise be favorable to the formation of a silicate of gold in siliceous auriferous rocks, and the subsequent solution of the compound and its transportation also from the massive rock into any cavity or fissure. There would thus be an infilling of fissures with silica, together with an admixture of silicate of gold, not to mention other minerals. Time alone would then be required to effect the complete separation of the gold from the silica with which it was united, and leave it as free metallic gold in the diversified forms and quantities in which it is now found in quartz veins. In support of this view Bischoff, Dr. Sterry Hunt and Prof. Newberry, all high authorities, have expressed the opinion that gold has probably been introduced into veins in the form of silicate.

The problem of the origin of gold, then, seems to be reduced to accounting for its occurrence in sufficient quantity in ordinary marine sedimentary rocks. As all the materials of these rocks were derived directly from the seas of the globe, it will be necessary to ask in the first place could the sea water contain and deposit the gold now embedded and disseminated in the rocks of the globe? This question can now be answered very distinctly in the affirmative.

Since the sea is the great receptacle for all solutions, it was safe to conclude that it contained the soluble salts of gold, but the fact is not now a matter of mere deduction, but of actual knowledge. Sonstadt found from careful experiments on the sea water of Ramsey Bay, Isle of Man, that sea water contains a little under a grain of gold per ton. Estimating the whole of the gold production of the world to the present time at £8,500,000,000 sterling, and taking the weight of the sea water of the globe at 560,000,000,000,000,000 tons, as was estimated by Prof. Wurtz, of New York, we find that the present seas of the globe contain upward of 5,000,000 times as much gold as has ever been extracted from the rocks, and consequently we must conclude that the seas of the globe in the past have been fully able to stock its mineral deposits with all the gold they contain.

We now arrive at the next stage of the inquiry, which is how can the gold be separated from its marine solution and be deposited along with the materials of the sands, the shales, the clays and the limestones that constitute the sedimentary rocks?

By the accidental dropping of a piece of cork into a solution of chloride of gold, Mr. Richard Daintree, of the geological survey of Victoria, discovered that organic matter causes the decomposition of an auric chloride solution and the consequent precipitation of metallic gold. During the deposition of the materials of the sedimentary rocks at the bottoms of the Palæozoic and Secondary and Tertiary seas, much organic matter undoubtedly existed on the sea bottom. Some strata are so crowded with the fossilized enduring parts of animal organisms that they are now actually named in geological nomenclature "bone beds" and "shell beds," and we have abundant evidence of the existence also through the geological periods of a great amount of algæ or "seaweed."

Assuming, then, that the waters of the seas of the past contained gold by the solution of its salts as our present sea water does, the conditions would be quite favorable for the deposition of gold contemporaneously with the accumulation of the ocean bed. The amount of gold thus deposited would, however, necessarily be so exceedingly small, in proportion to the mass in which it was included, as to be almost infinitesimal, and too little, therefore, to be detected in the resulting rocks, unless concentrated by separation from the general mass and accumulation in aggregations conjointly with other metallic mineral matter.

Consequent upon the important discovery of Daintree, Prof. C. Wilkinson carried out a long series of experiments, from which it was evident that gold precipitated by organic matter aggregated around metallic nuclei, and that besides gold itself, the sulphides of the metals, as pyrites and galena, were especially attractive. This is in entire accordance with the well-known fact of the association of gold with the metallic sulphides, and particularly with pyrites. When in association with pyrites or other metallic minerals, whether an association of adhesion merely or as an alloy, the gold would remain so associated until induced by the occurrence of new and favoring conditions to sever itself from its metallic associates, and chemically combine with an element or a compound for which under the conditions to which it was exposed it had affinity, and which body, I imagine, would be supplied by silica.

From these considerations it seems probable that gold was originally dissolved in the waters of the ocean, from which it was deposited, as the result of the decomposition of soluble salts of gold by the action of organic matter, and that it was then eliminated from sedimentary rocks by segregation to other metallic matter, with which it remained associated until thermal conditions (caused by deep-seated position or not far distant igneous action) induced a chemical reaction and likewise heated sufficiently the subterranean water of the rocks to make it an effective solvent of the auriferous compound. So the gold of the massive rocks was carried with silica by percolating water into the accumulating "vein stuff" of rock fissures, where on cooler conditions supervening, the auriferous compound was deposited in a solid condition, and the gold itself subsequently separated by the segregation of the silica to the vein quartz and left disseminated through the vein stuff as metallic gold in the forms in which it is now found.—Knowledge.

[ASTRONOMY AND ASTRO-PHYSICS.]

MARS *

By PERCIVAL LOWELL.

ON May 31, the date at which these observations of mine began, Mars was about 98 millions of miles distant from the earth, his south pole was tilted 23½ degrees toward her, and he showed gibbous to the extent of nearly one-sixth of his disk. The phase axis lay slightly to the left of the polar one.

These conditions continued substantially unchanged throughout the period covered by the observations, that is, from May 31 to June 24; the phase reaching its maximum of 47 degrees on June 16 and the tilt of the pole its greatest latitude at 24 degrees on June 22 (Marth). The phase axis meanwhile slowly shifted its position from the left to the right of the polar one. The planet passed through quadrature on June 16.

The observations were thus made from four and a half to four months before opposition and about equally long before the time of the planet's nearest approach; inasmuch as opposition will occur on the 20th of next October, and the minimum distance between the two planets be reached on the 13th of the same month. For satisfactory views to be had so unprecedentedly long before, so to speak, the event, the seeing, to secure which as good as possible the Observatory site was chosen, is responsible. What that seeing was the accompanying drawings will show. It was such as to enable me to make out a dozen of Schiaparelli's canals two months and a half before the summer solstice of Mars' southern hemisphere.

Most of the observations and all of the drawings, except the first, were made with the 18-inch. I may say here, however, that in questions of planetary detail of the inner planets of the solar system, up to and including Mars, size of instrument is quite secondary to quality of atmosphere. Large objectives give more light than small ones; that is their chief advantage. For faint stars this light is invaluable but for some of the planets such illumination were better away. Venus and Mercury are best studied in the daytime for this reason. Now, want of light is not the difficulty with Mars. During the dark the planet's glare was too great in the 18-inch. Details invariably came out best about three-quarters of an hour after sunrise. Yet the seeing at that hour was on the whole less good than earlier. From these observations and from certain ones of M. Flammarion, I am convinced that the post-sunrise and pre-sunset hours are the best ones for studying the planet. At other times a very faint dark glass might prove advantageous, or better yet, diaphragming the instrument down; then its focal length will tell over a smaller one. Simply increasing the power will not do, for atmosphere, owing to its inevitable lack of homogeneity, prescribes a limit. With the 18-inch at Flagstaff, a power of 420 was about this limit on Mars, although I have used 1,280 without sensible loss, though also without sensible gain. The greater number of my drawings were made with 370. On the six-inch 270 showed well, Lake Tithonus and the Agathodæmon canal being very evident as a dark line, and Argyre and Pyrrhae coming out with singular prominence—the dark and light markings being more contrasted, it is worth mentioning, than in the 18 inch.

How little this matter of atmosphere is duly appreciated is evidenced by the way in which a large instrument is assumed to be necessarily superior to a small one, quite irrespective of what it is that is to be observed. Now the fact is that there are two quite different classes of celestial phenomena; those dependent on quantity of light and those dependent on quality of definition for their visibility, and the two means to these ends go anything but hand in hand. For the one, the illumination, the size of the instrument is the prime requisite; for the other, the definition, the atmosphere is the first essential. As an object lesson in this it is worth noticing that the biggest instruments have not always given the best views of Mars. In matters of Martian detail it is amply evident from the results that observer, atmosphere, instrument is the order of weight to be given as the factors of an observation.

One preliminary result of the Arizona air may be worth noticing in the interest of astronomical concord, always so desirable. The quality of the seeing there suggests reconciliation between the very various drawings made generally of the planet. For Arizona seeing, too, had its ups and downs. When the seeing was exceptionally bad, Mars looked strikingly like his own photographs, as I remarked encouragingly to his photographer. A fact worthy of a word, for it seems to be overlooked in these days when celestial photography is the fashion—overlooked, not by the photographers but by the public, as I judge by more than one question put to me on the subject—that though photography will reveal what no eye can see, the eye will reveal what no photographic plate can show. Planetary detail falls under the latter head. For the difficulty of photographing such detail is not simply, as the inquirers suppose, a question of driving a clock timed first to the earth's rotation and then to the planet's space, which alone would require more perfect apparatus and a more complicated one than any yet devised. The deep difficulty lies in our own atmosphere, which is never steady enough; what is disclosed one minute being swamped by light waves the next. The attentive eye registers each glimpse, the photographic plate only the aggregate, and in the composite picture thus obtained the bad obliterates the good. With faint stars there is no such loss and every gain. For light is all that is wanted, however it be got. Now the eye cannot add impressions; the camera can. If therefore the camera be exposed long enough, it will reproduce what the eye could never detect. But, in the case of detail, the longer the plate is exposed, the more certainly will the detail be lost. Until, therefore, we rise above our atmosphere or find an absolutely faultless spot, we shall never be able, for planetary work, to match the eye by any film, however sensitive or accurately driven.

MARS

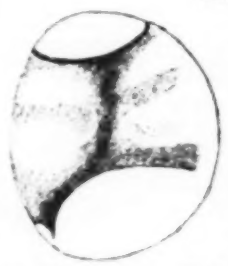


FIG. 1.—May 31. 17h. 48m. (Standard Mountain Time). Longitude* of center of disk 310°. Power, 340. The Hour Glass Sea on the extreme left. Strait visible connecting it with the Polar Sea. Aeria much the brightest land on the disk. Deucalionis and Noachis very faint.

FIG. 2.—June 2. 16h. 50m. (S. M. T.) Long. 276°. Power, 420. Lybia visible as a sort of snout. Having less sea next to the darkest marking on the disk. The Polar Sea the darkest.

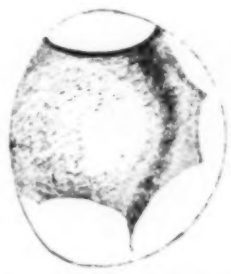


FIG. 3.—June 3. 17h. 14m. (S. M. T.) Long. 278. Power, 320. The beginning of the Nilosyrtis visible as a pig tail to the Hour Glass Sea. Strait between Polar Sea and Hour Glass Sea well seen.

FIG. 4.—June 7. 17h. 45m. 18h. 15m. (S. M. T.) Long. 344°. Power, 370. Star points on following end of snow cap. Preceding part dusky. Aeria on the limb, brightest part of the disk except the polar cap. Limb white, utterly unlike land. Beginning of Lethes visible in center of disk. Cloven shape of Heilas shown where Peneus debouches.

In the next higher stage toward atmospheric steadiness Mars assumed his old-fashioned, orthodox appearance, quite guiltless of canals and such-like inexplicabilities, an appearance which the admirable drawings of Mr. Green have raised to the rank of portraiture, and to the finality of which the Royal Astronomical Society, by its skepticism of Schiaparelli, has done so much to commit itself. Under better air, however, the disk began to show symptoms of heresy to these established Anglican views; until finally in the best moments the planet's surface came out with all the clear-cut character of a steel engraving, as Schiaparelli and Terby have described it. From the manner in which these happy revelations played bo-peep with the eye, it was evident that their intermittent invisibility was not chargeable to Mars' atmosphere but to our own. A canal or a coast line would suddenly stand out perfect-

* Communicated by the author.

* Longitudes are all from Marth. Details seen a few minutes, before and after, included in the drawings.

ly distinct several hundred miles in length, and then as suddenly be waved, by our own air, out of existence. The northern coast of the Mare Sirenum came out in this manner on June 24; and three canals, centering like the spokes of a cart wheel about a lake for hub, probably the Araxes, the Eumenides and the Agathodæmon about the Lacus Phœnicis, did the same on June 23.

So much for the terrestrial conditions under which the observations were made. The Martian ones were

FIG. 5.

such as to make the polar cap and its accompanying phenomena the center of interest upon the planet.

In the matter of the compass points, I would say that I make use of the orientation proper to the planet, that is east is east to one on the surface of Mars. This is similar to our own terrestrial orientation. The south pole of Mars reached its maximum dip toward the earth on June 22. It amounted then to 24°, an inclination greater than it has shown us for fifteen years, or will show us for fifteen years to come. Its south polar regions were in consequence peculiarly well

FIG. 6.

displayed, and this at the time when the snows there were in active process of melting.

At the beginning of the period included in these observations, the area covered by the snow cap was still very large. On June 3, I made it 47° across, that is, it covered nearly the whole frigid zone. During the month it decreased slowly in size. On June 19 it measured about 39°. But I think the former of these determinations somewhat too large and the latter a trifle too small. Throughout all this time its outer edge looked to me to be perfectly elliptical, implying, that is, that it was in fact perfectly circular.

FIG. 7.

Girdling it was a narrow dark streak of nearly uniform width, as seen at any one observation, but which slowly narrowed as the longitudes grew less. The snow was continuously bordered by this belt, which was broadest between 320° and 220° of longitude. Here calculation showed it to be about 350 miles wide. Farther east, above the Mare Sirenum, it had contracted to the half of this. It was clearly water at the edge of the melting snow, a polar sea in short. And it is worth noting that it was widest where the dark markings, the seas, were greatest in extent. Between Hellas and the Chersonesus its surprising symmetry

FIG. 8.—MAP OF MARTIAN SOUTH POLE.

The stars represent the brilliant points seen, indicating high land.

was broken by an expansion into a great gulf two or three times the width of the rest of it. Under the best seeing the gulf showed a beautiful deep blue.

On the morning of June 8, at 1h. 17m. G. M. T., I observed suddenly a couple of extremely brilliant star-like points upon the snow cap n. f just above this great bay. They were very conspicuous, resembling exactly the starry dazzle from a distant surface, tilted at the proper angle for specular reflection. A few minutes later they had disappeared. Just such an effect would be produced by snow slopes suitably illumined turning through the glinting angle. We have here then, in all probability, evidence of differences of elevation in the snow cap, of mountains there in short. Their position proved to have been in long. 291° 30'; lat. 75° 40' south. This, together with the known direction of the sun at the time, enables us, assuming specular reflection, to tell the tilt of their slopes. At that point upon the disk under the then illumination from the sun, the tilt of a slope capable of sending specular reflection, to the earth would have been 54½°, and the slope must have faced 9½° west of north. This is a surprising steepness, but fortunately absolute specular reflection is not needed to account for the phenomena. At so great a distance a surface tilted at a much lower angle, if of high reflective power, would produce a like dazzling effect, and for other reasons it is probable that the Martian slopes are not excessive. At the same time phenomena have been observed which seem to require some height in these hills, making them another of the puzzling points about this interesting planet. I shall resume discussion upon the snow cap in a later paper. Their position, it will be noticed, corresponds with the star points seen by Green in 1877 and by Mitchel in 1845, only that they were then seen as distant snow islands, the polar cap having disintegrated further.

On the morning of June 10, at 0h. 10m. G. M. T., I saw similar star points appear in about the same relative position on the disk, less bright than the first ones, and from the longitude then on the meridian, situated further to the east of them. I saw such again on the 11th, the 13th and the 14th at hours which showed them to belong to a long range of heights on that side of the snow cap. Sometimes they glittered like stars, sometimes they appeared simply as perfectly white spots.

Meanwhile on June 9 I had my first certain view of the great rift. It came out as a dark line roughly parallel to a parallel of latitude in the midst of the snow, about 15° from the lower edge of the cap, and nearly half as long as the cap's diameter. After this I saw it under varying angles of rotation, as will appear from the drawings.

On the 13th it showed cornerwise on the following side of the cap, back of the great polar bay. The phenomena on this morning were particularly detailed. Above the bay the snow glittered with the bright points I have spoken of, and then back of them fell off shaded to the rift. The rift itself appeared in the form of a half cross or notch in the heart of the snow at the base of the hills.

On the 14th I marked the rift debouch into the polar sea. At 17h. 30m., mountain time, that is, 15d. 0h. 30m. G. M. T., the entrance to it was on the meridian. The longitude of the rift's eastern end was therefore 160°. The rift was very broad, apparently equally so throughout, and looked like a huge cart track coming down to one over the snow. On the 15th I estimated its breadth at one-eighth of the cap's diameter. The same morning I also made a comparison of it with the scale of artificial canals. The values computed from the two determinations agreed perfectly, giving it a breadth of 220 miles.

On the 12th I noticed star points on the preceding side of the cap. This was then to the east of the rift and indicated, therefore, high land on that side of it, as well as on the other, tilted also to the west of north. Later the preceding end lost its luster and the following end had once more become the brighter.

From these observations and others at this observatory on the western portion of the rift, I have drawn a plan of the polar cap and marked it for elevation, as given below. The length of the rift would therefore seem to be about 1,200 miles.

Next to the snow cap the most striking feature about the disk was the emphatic tripartite character of its markings. The surface of the planet was conspicuously divided off into three distinct portions—the continental area, the polar cap and the area of dark markings or lying between the two. Though in no sense zones, these corresponded in a general way with the equatorial, the south temperate and antarctic regions respectively. Of zones proper there was, with the exception of the polar cap, no evidence whatever, which means of course that no cloud formations typical of them were visible; Mars being in this respect utterly unlike Jupiter or Saturn, where all that we see is cloud evidence of zone.

The three portions referred to may be recognized in any map of Mars; it was their marked contrast that was striking. For, next to the sharp manner in which the snow cap stood out upon the disk was the definite character of the continental coast line and the equally indefinite character of all the markings between the two. The coast line was most salient and clear cut on the western side of the Hour-glass Sea (Syrtis Major or Mer du Sablier). To the eastward the coast lay in general direction straight, approaching the pole as it stretched eastward. It was indented by numerous bays, but destitute of those comet-tail peninsulas so generally observed connecting it to the chain of islands south. All of these islands, Hellas, Ausonia and the rest, were vague, without definite contours, and lapsed imperceptibly into the surrounding seas. Even in color, they were less decided than, though of much the same tint as, the continental areas.

No connection appeared between the continent and the islands till it came to the eastern end of Mare Sirenum. Here Icaria and Phætontis made a bridge of singularly uniform width, preposterously straight and narrower than usually figured. Beyond this, to the east, Thaumasia appeared, at times well defined, at other times not. Lack of contrast, not lack of contour, was responsible for this, as the glimpses of it showed.

The colors of these three portions of the planet's surface were as marked as their contours. In the best seeing the colors were exquisite. During the dark the polar cap was straw color, the seas a limpid bluish green, and the lands a brilliant rose-orange. With the sunrise the snow cap turned to white, the seas to sky-blue and the land to a rosier red. The sky-blue of the seas was almost exactly the same tint, only a trifle fainter, as the blue of the surrounding sky, a sky, be it remembered, of over 7,000 feet of altitude. The light of the sun, filtered through our atmosphere, added blue to all, thus wiping out the yellow. A similar effect is visible in Venus and the moon, which from pale yellow by night turn pale white by day.

It may be noted in passing, that these before and after sunrise hues seem effectually to dispose of the suggestion that the seas owe their color to contrast. Were that so, then when the changed light had made the lands less yellow, contrast should make the seas seem more yellow, and not, as was the case, more blue.

For purposes of comparison with terrestrial objects, the post-sunrise tints are of course the ones to take. The resemblance in color therefore between the so-called seas and water scarcely needs comment.

Next in point of general importance come the phenomena of the terminator and limb. The terminator differed alike from the terminator of the moon and from the terminator of Venus, both of those bodies

FIG. 9.—June 9. 17h. 20m. (S. M. T.) Long. 214°. Power, 370. Rift in snow cap. Following part of snow cap peculiarly brilliant. Cyclops Cerberus (together) and Galaxias in center of disk. The former ends in a black dot, possibly the Trivium Charontis. Great Polar Bay visible on following edge of snow cap.

FIG. 10.—June 13. 18h. 40m. (S. M. T.) Long. 194°. Power, 370. Rift well seen. Star points following it. Southeast of them, the snow cap lies shaded to the rift. Cyclops and Cerberus on the right of disk. Suspected Trivium Charontis at bottom. Polar Bay well seen.

FIG. 11.—June 15. 17h. 30m.-18h. (S. M. T.) Long. 161°. Power, 640. Rift on the meridian.

FIG. 12. June 16. 17h. 20m. (S. M. T.) Long. 145°. Power, 370. Rift on following end of cap. Orcus at the Nodus Gordii in the center toward the bottom of the disk.

FIG. 13.—June 17. 16h. 38m. (S. M. T.) Long. 155°. Power, 370. Titan, Gigas, and Gorgon.

FIG. 14.—June 19. 17h. 45m. (S. M. T.) Long. 123°. Power, 370. Rift again. Gigas and Sirenius. Icaria and Phætontis strangely straight.

FIG. 15.—June 20. 16h. 40m. (S. M. T.) Long. 96°. Power, 370. Lake of the Sun, Phasis, Araxes Eumenides. Araxes the boundary of a shaded area.

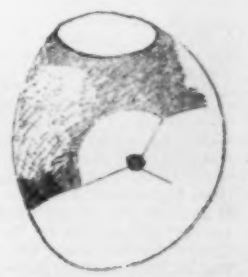


FIG. 16.—June 23. 18h. 20m. (S. M. T.) Long. 21°. Power, 370. Probably the Lacus Pœnicis with Agathodæmon, Araxes, and Pyriphlegethon.

opportunely offering themselves for comparison in the course of the month. The Martian terminator was more marked than the lunar one, less marked than that of Venus; that is, the shading was greater in the one case, less in the other. It would thus seem to imply for Mars a depth of atmosphere between the two.

The softening of the light was evident the whole length of the lune that was lacking. Even the polar snows showed it, being distinctly shaded on their preceding portion, notably on May 31 and June 7. The rest of the terminator was similarly darkened, the dark parts being darker and the light less light than the center of the disk. Only one exception to this did I observe: on the 24th, when a light band lay along the edge some twenty-five degrees wide over the sea area. This may have been caused by Argyre and Pyrrhae,

then upon that portion of the disk, though not distinguishably visible.

I saw no irregularities upon the terminator, although the terminator of Venus, with the same power, seemed not rigidly correct, either at the cusps or the fringe's inner boundary, and that of the moon stood conspicuously notched to the naked eye. On the terminator of Mars the only projections were the bright areas which projected in a body, an effect palpably due to irradiation. It seems, therefore, safe to say that few, if any, mountains relatively comparable to the lunar ones exist on Mars. The elevations otherwise revealed are probably of no great height.

The aspect of the limb was more suggestive, if harder to explain. The limb was very luminous and yellow. This luminosity was not confined to the actual limb, but extended a long distance on to the disk. It was as if a wash of some lighter tint had been laid on around that side of the picture; at times it showed an inner edge of demarkation as abrupt as a wash of water color. I saw it thus on June 15. An estimation of its breadth relatively to the radius of the disk made it 29° in from the limb, or two hours in time. As the limb stood at nine o'clock of a Martian morning, this corresponded to eleven o'clock in the day. So abrupt an inner contour is doubtless an effect of contrast, but it implies a pretty rapid falling off in the light.

With the exception of the polar cap and its surrounding polar sea, all detail near the limb was lost in this light, and to a distance in from the edge proportionate to the intrinsic contrast of the detail. The surpassing brilliancy of the snow cap and the darkness of the water beneath it caused these to stand out up to the edge. The sea area below them sometimes showed to the limb, sometimes not; the dark patches nearer the equator, to my eye, never. Roughly speaking, the farther from the pole the point on the surface lay, the farther from the limb was it obliterated.

Reversely every bright portion of the planet was brighter when upon the limb. The most striking instances of this were the islands like Hellas. This when coming around the corner shone with a brilliancy almost rivaling the polar cap. Yet so soon as it was well in evidence it was content to sink almost out of sight during the rest of its journey across the disk. Such first putting in of an appearance and then lapsing into obscurity was a specialty of islands; but once I marked, for some singular reason, both the islands and the coast line—in this instance Electris and Zephyria—thus singled out for initial prominence. Whether islands and coasts are more covered by moist air is a question suggested by these phenomena.

Such impartiality of obliteration shows, however, one thing: that the light along the limb is not due, as has been suggested for somewhat similar phenomena on the lunar limb, to reflection from mountain slopes or other irregularities of the surface. Nor does it seem attributable to cloud properly, so called, since we can hardly suppose clouds to be so superior to latitude, or to be so idiosyncratic as to remain till 11 o'clock in the forenoon and no later. We are thus apparently forced to fall back on atmosphere pure and simple, with probably much aqueous vapor in suspension.

Collateral proof of some such homogeneous veil, rendered opaque only by its thickness, appeared on July 15, when Hellas, then on the limb, stood out embossed on the light surface preceding it. The light surface was, in fact, a dark strait, but the whole had been illuminated by the light of the limb.

We now come to what we have at present every reason to believe to be water, the dark patches. A part of them may be vegetation, of which more later; but a part can hardly be anything but water, and perhaps all may be.

These dark patches, or as we may say provisionally, seas, were of diverse degrees of darkness, but each tint merged imperceptibly into the others. They looked to me to differ in degree, not in kind. The darkest of them was the polar sea, with its great polar bay. In the best seeing this last appeared deep blue, its size enabling the color to come out. The next darkest was the Hour-glass Sea (Syrtis Major); then the Syrtis Minor and the Sabaeus Sinus. All these are small patches, irreverently suggesting puddles, or deeper spots in the general water waste. Next to them in tint was the strait between Hellas and Pyrrhae connecting the polar and Hour-glass seas.

To the eastward of the Syrtis Major the tint of the seas grew lighter, and the same was true to the west. Indeed, the Hour glass Sea seems to be the center of the oceanic system of the planet. Not only does it lie at the apex of the largest water area on the planet; it is, with the exception of the temporary polar sea, the darkest and therefore presumably the deepest body of water there; but it makes a sort of funnel to discharge these waters into the various canals through the Nilosyrtis, the largest of their number.

This brings us to the canals. The first one I saw was on June 7, the Cerberus in all probability from its position. On June 9 it appeared persistently. I noted it as looking very broad. When on the meridian I glimpsed it double. I had only one glimpse of it as such, and though this was definite enough, I put no very great faith in it. I mention its duplicity for future verification. On the 9th and more certainly on the 10th, another canal showed debouching into the same bay, but turning more to the right, as it went northward, the Galaxias perhaps. I next thought I saw in the very middle of the continental area a part of the Orcus parallel roughly to a parallel of latitude. I never familiarized myself beforehand with the region about to be seen. During the next week I made out Gigas, Titan, Gorgon, Sirenius and Eumenides. The darkest of these was Eumenides, though it was the least well placed for observation. Up to this time the canals were of great difficulty, and were neither sharp nor phenomenally straight; fugitive glimpses, many of which flitted before me, but of which I have recorded only the more certain ones. But when the region of the Lake of the Sun began to come round, the canals in its neighborhood came out in much better shape; Phasis, Eumenides and Agathodæmon. Detailed explanation of the drawings will give a better idea than I can do in the text of the observations.

The general outcome of these early observations is suggestive. For the phenomena seem to point to a vast vernal freshet, now in process upon the planet. In the first place we see the great polar snow cap vanishing under our eyes. Now this might take place either by evaporation or by melting. Doubtless it does take place in both ways, but what is of interest is that we have direct evidence of the latter process. Instead of simply growing beautifully less, the snow cap appeared persistently fringed by a dark line which steadily kept pace with its retreat. This can hardly be anything but water, although it may be water in a very different condition from what we know it, neither fresh nor salt, for example, but something unlike either. The character of the water is, to a certain extent, a vital question, as irrigation with salt water does not commend itself to our notions.

Now so much water suddenly produced has got to be disposed of. For it is in a state of unstable equilibrium. So long as it was snow it stayed where it was. But the moment it melted gravity would pull it from the pole. Here step in the next observed phenomena. The bluish cast of the south temperate belt and the indistinctness of the contours of the islands there hint that this whole region is undergoing submersion and submersion of a sudden and temporary character. For in the first place we know that at other seasons these islands are both more conspicuous in color and more distinct in form, and that the comet-tail peninsulas now invisible appear with all grades of distinctness. In the second place, if this submersion were not of a temporary character, the contours of the red portions would be more definite than they are. For a marsh does not remain a marsh for long time; it becomes either land or water, by reason of the forces at work upon it.

Thirdly, the canals of the continent are well known to be less visible at this season of the Martian southern hemisphere. This is precisely what should happen if they are canals, especially if what we see are the effects of the water in them rather than the water itself. For it would take time for the effects of a flood, in the way of vegetation, for example, to show themselves. Now it is rather significant in this connection, that the canals now best seen should be those nearest the south pole, namely, the ones about Thaumasia and Mare Sirenum.

So much for the positive evidence of the circulation of water as water upon the planet. The evidence of its circulation as cloud is negative. There is no sign of cloud apparently at this season. Although the air is probably charged with vapor, it does not condense into cloud or fall as rain or snow. Even occasional indistinctness of detail seems, as we have seen earlier in this paper, to be due to our atmosphere, not to that of Mars. At this spring season of the southern hemisphere the Martian aqueous circulation seems, therefore, to be chiefly a surface one of water.

Here we have a raison d'etre for the canals. In the absence of spring rains a system of irrigation seems an absolute necessity for Mars, if the planet is to support any life upon its great continental areas.

It is specially important that phenomena like these spring phenomena should be reasoned on. For it is chiefly by collation of inference that we are likely to build up a true knowledge of this our neighbor world. We shall best explain such enigmas as the canals by getting greater insight into the general physical conditions existing upon the planet. It is by no means inconceivable that we may first succeed in unraveling that network of seemingly incomprehensible lines by inevitable inference from comparatively simple data.

Lowell Observatory, July, 1894.

HAFFKINE'S CHOLERA INOCULATION.

IN a report made by Dr. W. J. Simpson, health officer of Calcutta, on inoculation with the cholera vaccine practiced by Haffkine, published in the Indian Medical Gazette, the following results are detailed:

"The inoculations were done in various parts of the town where cholera was prevalent, and there are several instances of cholera being apparently arrested by the inoculations. But the most important observations are to be obtained under condition when the disease continues and allows of a comparison between the inoculated and the non-inoculated. Such a condition presented itself in the case of a local epidemic, which took place around two tanks in Kattal Bagan Bustee, Ward 19, occupied by about two hundred people. In this bustee, about the end of March, two fatal cases of cholera and two cases of choleraic diarrhœa occurred. The outbreak led to the inoculation of 116 persons in the bustee out of the 200. Since then nine cases of cholera, of which seven were fatal, and one case of choleraic diarrhœa, have appeared in the bustee, and it is a very extraordinary fact that all these ten cases of cholera have occurred exclusively among the uninoculated portion of the inhabitants, which, as stated, forms the minority in the bustee, while none of the inoculated have been affected."

Dr. Simpson describes the method of obtaining the cholera vaccine and its application, as follows:

"The problem which, therefore, had to be solved in the preparation of a vaccine against cholera, was to find the means of fixing the virus in a well determined strength, and to be able to keep it for an indefinite time at that known strength. Professor Haffkine solved the problem. He discovered a means of engrafting on animals the cholera microbe, and cultivated it indefinitely on such animals. This gave him vaccine. At the same time he was able to increase the cholera microbes to a strength which produced with certainty a specific infectious disease on animals, and against which he was able to protect them.

"For cholera inoculation there are two vaccines, one mild, the other strong. For a complete vaccination it is necessary to inoculate twice; first of all with the mild vaccine, which produces some pain at the seat of inoculation, discomfort, and fever for about one day; a period of five days is allowed to elapse; and then a second inoculation is performed with the second or strong vaccine. This second inoculation produces a similar form of malaise to that caused by the first. This discomfort, on the whole, is milder and of shorter duration than that of vaccination against smallpox. Its harmlessness was established by very careful and patient observation on medical men and scientists, who were inoculated in Europe soon after the discovery."

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